

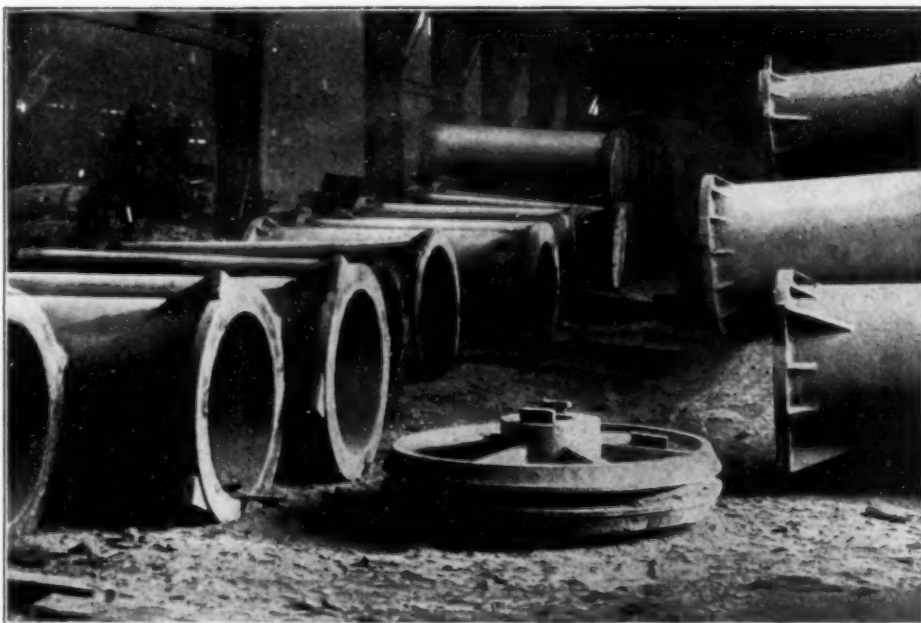
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Ready Reference and Alphabetical Indices, Pages 76 to 79

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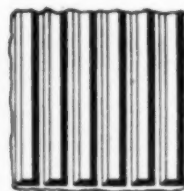
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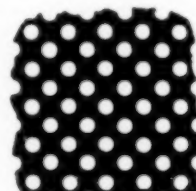
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NEW YORK, JULY, 1914

EDITORIAL:

| | |
|---|-----|
| The First Chandler Lecture..... | 427 |
| The Cost of Noise..... | 427 |
| Welfare Work in the Steel Industry..... | 428 |
| Industrial Peace and Professional Ethics..... | 428 |
| Craft, Cunning and Intelligence..... | 429 |

READERS' VIEWS AND COMMENTS:

| | |
|--|-----|
| Rapid Evaporation of Solution in the Determination of Silica and Alumina in Iron Ores. By W. S. Wurtzel..... | 430 |
| Is There a Complex Ore Problem? By Parker C. Choate..... | 430 |
| Definition of Alloys. By C. J. Thatcher..... | 430 |
| The Western Metallurgical Field..... | 431 |
| The Iron and Steel Market..... | 433 |
| The Non-Ferrous Metal Market..... | 434 |
| Troy Meeting of American Institute of Chemical Engineers..... | 434 |
| Ninth International Congress of Applied Chemistry..... | 435 |
| Paris Meeting of British Iron and Steel Institute..... | 436 |
| A Mine at the San Francisco Exposition, 1915..... | 436 |
| Some Professional Obligations. By M. C. Whitaker..... | 437 |
| Physical Versus Chemical Action in Furnaces. By Carl Her- ing..... | 439 |
| Electrolytic Refining of the Precious Metals. By H. Lacroix..... | 441 |
| Superheated Steam and Railway Locomotives..... | 443 |
| Electric Iron Smelting at Hardanger in Norway. By John Harden..... | 444 |
| First Chandler Foundation Lecture..... | 446 |
| Chemical and Industrial Applications of Mechanical Refrigeration. By H. J. McIntire..... | 447 |
| Copper in Scotland..... | 448 |
| Notes on Unit Cost-Keeping in Metallurgical Work. By Justin H. Haynes..... | 449 |
| The Construction of the Blast Furnace Stack. By J. E. Johnston, Jr..... | 451 |
| Colorimetric Estimation of Gold in Cyanide Solution..... | 460 |
| Three Metal Bronzes. By Allmand M. Blow..... | 461 |
| Notes and Observations on Ore Treatment at Cobalt, Ontario, Canada. By H. C. Parmelee..... | 467 |
| The Story of Mining and Metallurgy. By T. A. Rickard..... | 469 |
| Is There a Complex Ore Problem? Contributions by F. L. Clerc and L. D. Godshall, and Editorial Summary..... | 471 |
| The Application of Physical Chemistry to Industrial Processes. By Walter F. Rittman..... | 475 |
| RECENT CHEMICAL AND METALLURGICAL PATENTS..... | 479 |
| SYNOPSIS OF CHEMICAL AND METALLURGICAL LITERATURE..... | 480 |
| An Economic Way to Handle Shipments of Long Iron Rods..... | 482 |
| Filter Press Experience in a Cuban Sugar Plant..... | 482 |
| Electric Annealing Furnace for Brass and German Silver Ware..... | 483 |
| PERSONAL..... | 485 |
| DIGEST OF ELECTROCHEMICAL U. S. PATENTS (Electroplating)..... | 485 |
| BOOK REVIEWS..... | 486 |

The First Chandler Lecture

The celebration of the fiftieth anniversary of the Columbia School of Mines was the occasion of a wonderful outpour of love and affection for its only surviving founder, the dean of chemistry in America, Dr. Charles F. Chandler. It was the psychological moment for the fitting inauguration of the lectureship which is to commemorate forever Chandler's name at Columbia. And as Dr. Baekeland was the lecturer, it goes without saying that the first Chandler lecture was brilliant and worthy of the occasion.

Under these conditions our apologies would be due to our readers for not publishing in full Dr. Baekeland's lecture in this issue, if it was not for a remarkable clause in the Chandler Foundation to the effect that the Chandler lecture is first to be published in the official "Quarterly" of the School of Mines, which may mean a delay of a month or two. Of course, such a clause, like any attempt to put a release date on any speech made in public, is absurd. It can be legally enforced only if the Chandler lectures are to be star chamber proceedings. Is this the intention? Or is it a suggestion that watchful waiting is a good preparation for prospective readers of Chandler lectures? Or it is an attempt to cripple live technical newspapers in favor of their slower brethren? We can't conceive of any sensible reason, if widest publicity is really desired for the Chandler lectures. Or is the reason psychological? Was it simply a case of Homer nodding?

The Cost of Noise

In a recent conversation the superintendent of a large stamp mill made the observation that "noise costs money." We had been discussing the use of stamps as crushing machines and the comparative merits of various devices for crushing ore. One of the arguments advanced by this superintendent against the use of stamps was the tremendous and never ending noise produced by the falling weights. In his opinion the din was responsible for many misunderstood directions and orders to employees, resulting in confusion, loss of time, and expensive mistakes. The point is readily perceived. The average mill employee is anxious to give the impression that he understands the boss's orders, and rather than ask a question for further information he will sometimes pretend to understand and then go and seek advice from a fellow workman. The order may be wrongly executed or not at all. The noise of the stamps contributes greatly to this condition, makes it difficult to give and receive orders, and undoubtedly causes many mistakes. The cost of noise may not be estimated exactly, but it is a real factor.

Welfare Work in the Steel Industry

Eleven years ago, when the annual scale settlement was made between the Amalgamated Association of Iron, Steel and Tin Workers and the union tin plate mills, the only change made in the scale was the adoption of the following paragraph: "That the company furnish ice or well water to its employees." Considering the nature of the work at the hot mills the demand of the men, thus complied with, was certainly a very modest one.

The incident gives us a viewpoint. When barely over a decade ago it required the demand of a fairly strong labor organization to secure suitable drinking water for men whose occupation required them in summer to drink water not by the quart but by the gallon per turn, it is doubtful whether we are able, without such checks, to realize the sweeping character of the welfare work which has been in progress in recent years in the steel industry.

Again, if we do realize the extent of the work which is going on there is a possibility of misjudging the influences which cause it. Our London contemporary, the *Iron and Coal Trades Review*, for instance, with what is almost a covert sneer, suggests that the United States Steel Corporation, recognized as the greatest leader in this work, is defending a suit by the government for its dissolution under the Sherman anti-trust law. Who could prove his ground for an assertion that it is because the Steel Corporation has been under fire that it has undertaken these things? That it is because the corporation is very large that it has done so much is, on the other hand, a statement which can be supported by much circumstantial evidence. Among the "independent" steel manufacturers, for instance, it is commonly found that the larger the concern, the more welfare work has been done. There is ground, in the existing facts, for formulating a general principle that the larger the manufacturing interest the more likely it is to adopt comprehensive plans for improving the working and home conditions of its employees. The work has been principally of a pioneer nature and large interests are more able to do such work than small interests. When practices have become well established the difficulties in the way of the smaller interests are removed.

Welfare work, including mill sanitation, establishment of hospital departments, beautifying mill surroundings, provision of rest places, protection against accidents, playgrounds for employees' children, encouragement of home gardening and the like, are already yielding tangible and direct results. There is no question that "they pay." There is little danger of making mistakes. The various efforts that have been put forth have almost invariably been strikingly successful, and this is a greater proof of the propriety of the work than is generally recognized.

Compare, if one will, the failure of so many systems of profit sharing. Welfare work as we know it is much less than a decade old. Profit sharing is many decades old, and yet with all the experience gained the failures have been so many that the question may well be raised

to-day whether there is any known system of profit sharing which can be guaranteed to give adequate results.

Certainly there are very recent instances of absurdly inadvisable methods, the most glaring doubtless being that of the famous "car" builder of Detroit. It is the greatest possible tribute to welfare work that it has been so signally successful in its very earliest years when after decades of experiments so theoretically desirable a principle as profit sharing cannot yet be carried out with anything like similar success.

Industrial Peace and Professional Ethics

The last graduating class of the Colorado School of Mines was honored at the commencement exercises by an address from Dr. Rossiter W. Raymond, whose subject was "Professional Ethics." Filled with excellent advice on a phase of professional life too often neglected, the address came as a fitting close to four years of absorbing application to technical studies, as well as a practical introduction to an honorable engineering career.

The ethical principles of life are simple in formula, and well known to all educated men; but their consistent application to life seems difficult on account of the complexity and multiplicity of human relations. Thus, unless studiously avoided, morality among men may come to be a relative matter of training, experience and interpretation of principles, often leading to perverted reasoning and resulting in the acceptance of misleading half-truths, such as "the end justifies the means." Comparing man's relations in war and peace, Dr. Raymond finds that the recognized elements of warfare have been adopted in business. Speaking of war he says that "perhaps its greatest evil result is its corruption of the ways and habits of peace." Certainly industrial peace is coming to be recognized as a desideratum far above the success that is coincident with, and dependent upon, acts of warfare and piracy in business. Hence the need for "honesty, justice and fair play," which are accepted among us as the principles of ethics.

Touching directly on the ethics of engineers, chemists, and metallurgists, Dr. Raymond outlined some of the obligations which are imposed on men in those professions: as authors, as employees, as factors in business transactions and as advisors.

The ethics of authorship, either of reports or papers, demand that the writer shall not pretend to knowledge that he does not possess or ability that he has not acquired. Authorship implies a contract on the part of the writer to present clearly and logically to the mind of the reader those things to which he makes legitimate pretense of knowledge. He is not justified in creating a false impression to gain personal ends, nor in appropriating as his own the language of others.

As an employee an engineer must possess and display the quality of loyalty as well as ability. This is "dictated by honor, and even by selfish interest." How rare is the employee who shows the same devotion to

his work that is felt by his employer. Ability counts for little in personal equipment if it is not supported by loyal devotion. "The time is past when the master could watch all the details"; and with the development of vast enterprises involving the co-operation of many men, the demand for loyalty is greater than ever before.

As a business agent the engineer must act in perfect faith and maintain his integrity unquestioned. The secret commission on purchase of property or equipment is one of the most insidious forms of temptation to forget or neglect the interest of a client. Secret acts sooner or later come to light, and usually at a time when explanations are difficult or impossible.

In advising clients on professional matters the engineer must be free to tell the whole truth, not suppressing any pertinent facts. His reports should be made in such a manner that they cannot be misconstrued or garbled by unscrupulous persons. In giving expert testimony in litigation he should not take the witness stand unless he has examined the case and believes that he can be of service to his client; nor should he serve his client for money to the detriment of his own good name and reputation.

The spirit of the time demands fair play and a square deal. The engineer must be frank, open and above board in all his dealings, and must preserve his integrity by avoiding complications that may arise from the disclosure of secret acts. With the speaker at Golden we may say, "Do not do what you could not tell without shame," and likewise ask, "Why not walk in the light?"

Craft, Cunning, and Intelligence

Words like metals have varying uses. Meanings like metals are of different degrees of purity. It can be laid down as an axiom that the word intelligence has the meaning in its broadest sense that connotes the ability to see and remember things with the result of being able to accurately foresee the future. If one will examine life and foresee the common use of the word "intelligence" he will see that people usually mean just about that and nothing more, the ability to foresee the future, even though the future may be immediate. For instance, if a man were walking by an office building where a safe was being hoisted up and he crossed to the other side of the street we would call him cautious or prudent, but we would basically mean that he was intelligent. Man is a sentient creature, but he is distinguished from other creatures also sentient, such as animals because he has intelligence and it is by use of intelligence that he has arisen from savagery and has conquered nature.

The word intelligence can be used in a concrete sense or it can be used in an abstract sense. We can look to the effects of intelligence to understand it or we can understand it directly by subjective powers.

Probably all the ills of individual and state are caused by a lack of full intelligence. And in a narrower sense intelligence of the higher type can be differentiated from intelligence of a lower type, i.e. craft

or cunning. Craft is a word originally used objectively to denote the power of "doing something." Cunning derived from anglo-saxon word cognate with "can," likewise means ability "to do something."

Nowadays both these words—craft and cunning—suggest the ability "to do somebody." So it is in the disinclination of people to see the practical and efficacious difference between intelligence and craft that is the cause of what can be vaguely described as vague social unrest. It is plain that if the public frowned on or ostracised men that wrecked railroads to amass money by craft and cunning such men would cease to exist. But the public has had always a sneaking admiration for such men. The public kicks at the trusts, but in the past fifteen years have given ear with eagerness to the accounts in magazines and newspapers of the intimate life and pursuit of happiness of the individuals who have grown rich out of the trusts. It would seem to follow that the public is to blame in this respect and did not really know itself.

The word intelligence, however, has a broader, higher and nobler application. A man who grows rich by building up a railroad, does good rather than harm and he has gained his power by true intelligence, rather than by craft or cunning. The three words, craft, cunning and intelligence, have also a social application. Intelligence operates to benefit society, craft to hurt it. Intelligence sees clearly and works for its own good in part, but in larger part for the good of the community. It attains its unselfish ends, possibly with a selfish motive, but at least with altruistic effects. Craft or cunning simply looks to its own immediate good. By their fruits we must know them.

For instance, a rat is foxy because it escapes the trap and "gets away" with the cheese and a fox is ratty because it steals a chicken without being caught. From its own standpoint, a rat and a fox are eminently intelligent and unqualifiedly respectable—does not a rat wear dignified side whiskers and does not a fox brush himself daily?—but from the standpoint of man they are asocial agents and anti-social. Accordingly a foxy business man or a ratty politician—oily, slick articles—are asocial because each merely thinks of himself from the viewpoint of society each is not intelligent but cunning. It all depends on the viewpoint.

Now, if society could and would discriminate between intelligence on one side and craft or cunning on the other side, if the rewards were given for real work, not for results of "getting by" or "getting away with it" or "slipping something over," expressions of the vernacular so suspiciously frequent as to almost postulate their universal acceptance as true doctrine—we would have fewer lawyers and more good ones, real leaders of religious thought rather than ecclesiastical charlatans, statesmen—not mere politicians or demagogues, fewer militant suffragettes and more pleasing women, happy tillers of the soil instead of bad farmers, and the cost of living would go down.

Readers' Views and Comments

Rapid Evaporation of Solution in the Determination of Silica and Alumina in Iron Ores

To the Editor of Metallurgical & Chemical Engineering:

SIR:—In the estimation of silica and alumina by the method of fusion with sodium carbonate, every chemist is confronted with the problem of evaporating the solution in the shortest possible time. The water-bath is practically excluded on account of the long time required, and the operation usually is conducted in an evaporating dish placed directly on the hot-plate and covered with a large watch-glass. The drawbacks to this procedure are evident to all who have to do such work; there is too great a risk of loss by bumping, spattering, and overheating.

In order to obviate these difficulties, the writer has made use of the following device which has proved very satisfactory. Make a ring of sheet tin, $\frac{3}{4}$ in. high and $4\frac{3}{8}$ in. in diameter. This is suitable for use with an evaporating dish $5\frac{1}{2}$ in. in diameter; other dimensions can be used for dishes of various sizes. The ring is placed directly on the hot-plate and used as a support for the evaporating dish. No cover is required. With a ring and dish of dimensions given above, the bottom of the dish will not touch the hot-plate, and we have, in effect a hot-air bath on which evaporation will proceed under the boiling point of the solution. All of the vapors can escape readily, not being retained by or condensed on a watch-glass cover.

While the evaporation is proceeding the operator is at liberty to dispose of his time as desired until a point is reached where the residue appears just moist or damp. The dish should then be removed to a cooler place to prevent any loss by decrepitation of the chlorides, but as soon as no more vapors escape and the residue appears dry, it is safe to complete the dehydration on the hottest spot of the plate.

The advantages accruing to this method of evaporation are: The dish is more easily handled and cools more quickly when removed from the plate; the residue appears more homogeneous; no crust has to be washed from a cover; less solution has to be filtered, and the volume of the filtrate for the final determination of alumina is small. The operation requires less time.

S. WURZEL.

Sunrise, Wyo.

Is There a Complex Ore Problem?*

To the Editor of Metallurgical and Chemical Engineering:

SIR:—(1) Re: the "complex ore problem"; any ore is complex that will not show a profit when treated by the commonly known and developed metallurgical methods. All ores carry more than one possible value, and many a large number, and thus as industrial uses arise the complexity of commercially converting nature multiplies and the end is infinity.

(2) The presence of zinc "blende" in a form that is not amenable to mechanical separation is the usual reason for the word "complex." It most certainly is not the fault of the present methods in metallurgy or lack of skilled operators, but entirely the lack of commercial methods and application.

(3) In a broad sense we are not utilizing half the

*Mr. Choate's interesting communication was received after the communications by Messrs. Clerc and Godshall and the editorial summary which will be found on page 471 of this issue, had already been set in type and arranged in page form. Mr. Choate's communication is, therefore, printed separately at this place.—Editor.

value that our non-complex ores show us because the balance is uncommercial under the imposed condition, while there are innumerable examples of very large tonnages carrying heavy gross values that are not treated because uncommercial. Value is a vague term to use, as it may be interpreted to mean the metal value of the ore as gross, or net, and again, might be figured as the value of compounds of metals or constituents manufactured directly from ores.

(4) As applied to present practised metallurgical methods the presence of zinc "blende" existing with other sulphide is the most usual refractory element, but baryta, arsenic, or even other elements might render the ore uncommercial or complex.

(5) There will be no universal process that will solve the complex ore problem because it is not a universal problem. Roasting and slag smelting has had its day, but will be limited to ores where heavy values are not carried off in slags. Electric smelting will supplant much present cupola and reverberatory practice.

Mechanical dressing will always pay up to a point where waste does not defeat it. Processes for preparing ores for the pyrometallurgical process, other than mechanical, will play a part. Leaching and chlorination processes are clearly the best methods in many instances. Volatilization methods as steps in complete treatments or direct treatment for commercial separation of values are sure to become very prominent. Electrometallurgy as applied in refining, distilling, producing reactions now impractical, will fill voids not now realized by many.

(6) Microscopic examination would belong to the laboratory department to determine the nature of the ore; the treatment used must be governed solely by the commercial aspects. There is rapidly coming a revolution in metallurgy due to technical education, and progress lies in the hands of the inventor or research agent coupled with financial support to commercialize his creation.

PARKER C. CHOATE.

National Lead Company,
Brooklyn, N. Y.

Definition of Alloys

To the Editor of Metallurgical and Chemical Engineering:

SIR:—In your April issue, page 218, you quoted the decision of His Honor, Judge Hough, in the suit on the Welsbach patent, No. 827,017, for a Cerium Pyrophoric alloy, and which decision contains the statement: "The important words (for this case) are *two or more metals*, and all the experts examined agree that an alloy must contain that number."

Since the well informed readers of your journal know this definition to be incorrect, allow me to state that the Court erred in stating that *all* of the experts thus incorrectly defined the scope of the term alloy. In my own expert deposition in this suit, when the definition quoted by the Court was called to my attention in Q. 40, I replied: "an alloy may be formed by combining or mixing a metal with some *non-metallic* solid elements so as to form a solid coherent product." And, as I stated in my answer to xQ. 42, my opinion was confirmed by one of the opposing experts, who also described "such a manner of making an alloy—a *pyrophoric alloy*—of cerium and silicon."

CHAS. J. THATCHER.

New York City.

The Western Metallurgical Field

Chlorination at Park City, Utah

The chlorination mill of the Mines Operating Co. at Park City Utah, has been running steadily for several months at a capacity of about 165 tons of ore per day. During March 5000 tons of ore were treated from which 7 tons of precipitate were produced for shipment. The plant is reported to be operating at a profit. Filling from the Ontario stopes is being treated. This ore contains 9 to 10 oz. silver and 0.03 oz. gold per ton, 0.05 per cent. copper, 1.0 per cent. lead and about 1.0 per cent. sulphur. With the ore crushed to $\frac{3}{8}$ -in. size the saving is 80 per cent. of the silver, 90 per cent. of the copper and 30 per cent. of the gold. Some lead is also extracted but practically nothing is realized on it when shipped to the smelter. When crushing to 8-mesh, 90 per cent. of the silver can be saved.

This process consists essentially of crushing the ore to $\frac{3}{8}$ -in. size, chloridizing-roasting with salt, leaching with acid and salt solution, and precipitating the silver, copper, gold and lead on scrap iron. The ore first passes through a trommel with 1-inch openings, the oversize going to a gyratory crusher and the undersize to a stationary dryer. Seven per cent. salt and 2.8 per cent. coal dust are then mixed with the ore by feeding these materials from their respective bins on to a common belt conveyor. The ore, salt and coal dust mixture is crushed in rolls to pass a $\frac{3}{8}$ -in. trommel, and stored in bins over the roasters. Chloridizing-roasting is performed in 6 vertical blast-roasters, each of about 35 tons daily capacity. After roasting is completed, side doors at the base of a roaster are opened, and the hot ore is sluiced out of the furnace with weak, acid, mill-solution into a wooden leaching tank of which there are six. After settling for about 3 hours, the solution is drawn off through the bottom of the tank to the precipitation boxes. Barren solution is then turned on the tank for from 20 to 24 hours, passing to the weak solution tank for use in sluicing out the roasters. The tanks are then sluiced out with water. There are two series of precipitation boxes containing all kinds and grades of scrap iron. Silver is precipitated in the front boxes, followed by copper, with a predominance of lead in the last boxes. There is no marked dividing line in this precipitation as all the metals come down in all parts of the boxes, but there is sufficient distinction to be noted by the eye.

A novel feature of the plant is the type of roaster employed. It consists of a vertical shaft of square horizontal cross-section, with grate-bars in the bottom to support the ore, beneath which the air blast is introduced. The roasters are built of brick or concrete and lined with cement so as to give a smooth vertical wall. Wooden grate-bars are used, which are covered with about 4 in. of coarse and crushed ore to protect them from the heat. As they are wet by the solution in sluicing out the roaster and protected by the covering they have no great tendency to burn, especially with the blast driving the heat up and away from them.

The roaster is of intermittent operation as at present constructed. After a charge has been removed, the 4-in. covering over the wooden grates is stirred up by the laborers to prevent caking. A small amount of coal dust moistened with coal oil is then spread over the floor of the roaster. This is ignited, a little ore shoveled through the side doors, and then after closing the doors the furnace is charged to a depth of about 6 feet with the ore, salt and coal dust mixture from the ore chutes above the furnace. Charging and roasting take about 16 hours and discharging or sluicing about 6 hours. An experimental 9-ton roaster has shown the possibility of

modifying the furnace for continuous operation by the use of steel grates arranged so as to partly discharge the furnace when moved horizontally for a short distance. This roaster is always filled with ore. When the roast is complete, the grates are operated mechanically to lower the ore in the shaft about 18 in., when more of the mixture is charged at the top. Discharging in this manner is done about every $1\frac{1}{2}$ to 2 hours, taking not over 5 minutes. This furnace has considerably reduced the necessary labor.

The leaching solution used in this plant is barren mill solution from the precipitation boxes to which sulphuric acid is added in the barren solution tank. It contains from 3 to 4 per cent. of hydrochloric and sulphuric acids and as high as 20 per cent. salt. About 70 lb. of 60° B. sulphuric acid is added per 24 hours, or at the rate of about 0.42 lb. per ton of ore. Some bleaching powder is added in the leaching tanks, about 20 lb. per tank, to assist the solution of the gold. No difficulty has been experienced with fouling of solutions due to presence of iron. The solution does not contain over 2 to 3 per cent. iron. The precipitate from this solution contains 4,000 to 10,000 oz. silver and 1 to 5 oz. gold per ton, 30 to 40 per cent. copper and 10 to 25 per cent. lead. The scrap iron consumption is one ton of iron to a ton of precipitate.

The process employed at this mill appears to be working satisfactorily for the extraction of copper and silver from this low grade material. Wooden tanks and pipes, and air lifts are used for handling the acid solution. No more apparent difficulty is experienced with this solution than with ordinary cyanide solution. Wooden valves were used at first, but rubber hose and clamps are now installed and give better satisfaction. Materials are stated to cost laid down at the mill as follows: Coal dust, \$1.75 per ton; salt, \$4.45 per ton, and sulphuric acid, 1 cent per pound. As the smelter does not pay full value for the silver in the precipitate, a refinery would be added if a new plant were constructed. The silver and gold in solution would then be precipitated on copper, and the copper and lead on iron, thus producing a gold-silver bullion and blister copper.

Company Reports

From the annual reports for 1913 of four of the large copper companies the following tabulation of data is prepared:

| | Chino | Ray | Nevada | Utah |
|--------------------------|------------|------------|------------|-------------|
| Ore milled, tons..... | 1,942,700 | 2,365,296 | 3,139,137 | 7,519,392 |
| Copper content %.... | 2.033 | 1.719 | 1.599 | 1.247 |
| Conc. produced, tons.. | 183,117 | ..... | 452,233 | ..... |
| Copper content, %.... | 14.518 | 18.550 | 7.61 | 17.31 |
| Ratio concentration... | 10.61 | ..... | 6.94 | ..... |
| Percentage recovery.. | 67.31 | 66.09 | 68.52 | 63.95 |
| Milling cost, c. per ton | 61.08 | 51.93 | ..... | 36.76 |
| Cost copper, c. per lb.. | 8.787 | 9.784 | 9.99 | 9.498 |
| Ore reserves, tons.... | 90,000,000 | 78,880,966 | 39,108,590 | 332,500,000 |
| Copper content, %.... | 1.8 | 2.2 | 1.65 | 1.47 |

The operation of the Chino plant during the last seven months of the year clearly demonstrated an average mill capacity in excess of 6,000 tons per day. No additions of consequence were made to the mill except in the coarse crushing plant, where another crusher and set of rolls were provided to insure against delays. The low ratio of concentration was due to the high iron content of ore from certain parts of the mine, resulting in an abnormally large tonnage of concentrates and an increased cost in transportation and smelting. The installation of a plant for recleaning concentrate has improved this condition.

All of the eight sections of the Ray Consolidated mill have been completed and are ready for operation as needed. Some important changes made in the flow-sheet last year has enabled the management to increase the tonnage handled and at the same time improve the metallurgical results. The slightly increased

cost of milling was due to intermittent operation during the progress of construction. There has been a marked decrease in accidents at mine and mill, which the company attributes to its "safety first" campaign. A school of instruction for the avoidance of accidents, mine rescue and first-aid work is maintained, and prizes are offered to employees suggesting the best safety appliances.

The increased cost of copper production at the Nevada Consolidated was due to the lower ratio of concentration which resulted in increased smelting cost. An increase in wages also added 0.394 cents per pound of copper produced. Replacements and betterments were responsible for an increase of 0.19 cents per pound of copper. Many improvements were made in the concentrator in 1913, resulting in improved settling of slime and recovery of water, improved concentration and classification. At the Steptoe smelter the roasting plant was enlarged by the addition of two furnaces. In the reverberatory department there has been an increase in capacity of furnaces from 262 tons charge in 1911 to 371 in 1912 and 481 in 1913. The longer furnaces have not shown a reduction in oil ratio but show better costs.

The Utah Copper Co. completed in 1913 the alterations in the coarse crushing departments at both the Magna and Arthur mills. During the year when running on low-grade ore, the Magna plant demonstrated its ability to handle nearly 14,000 tons daily, and the Arthur mill over 10,000 tons. This gives an aggregate capacity of 24,000 tons daily for very low-grade ore. With material of average grade the economic capacity of the mills is about 21,000 tons per day. A decreased percentage of recovery is noted, due to the lower average grade of ore treated. The total cost of mining, transportation and milling was but \$0.9761.

From the seventh annual report of the La Rose Consolidated Mines Co., Cobalt, Canada, we take the following data referring to operations for 1913. The company produces high-grade ore for direct shipment, and low-grade rock for concentration by the Northern Customs Concentrator.

| | SHIPMENTS | | Per cent of Oz. silver total net value |
|------------------------------|-----------|----------|--|
| | Dry tons | per ton | |
| Silver-Cobalt-nickel ore.... | 1,275.8 | 1,500.8 | 75.7 |
| Low-grade silicious ore.... | 1,076.5 | 112.5 | 3.4 |
| Nuggets | 6.1 | 22,658.1 | 5.9 |
| Concentrates | 915.9 | 456.6 | 15.0 |
| Totals and average..... | 3,274.3 | 791.8 | 100.0 |

| COST OF PRODUCING SILVER | | |
|--|-------------|----------------|
| | Per ton ore | Per oz. silver |
| Mine operation | \$117.23 | \$0.1474 |
| Concentration | 30.90 | .0388 |
| Marketing ores | 48.96 | .0616 |
| Depreciation | 3.57 | .0045 |
| Corporation and traveling.... | .66 | .0008 |
| | \$201.32 | \$0.2531 |
| Less rents, interest and dis- counts | 19.96 | .0251 |
| Total cost production..... | \$181.36 | \$0.2280 |
| Cost of production amounted to 38.62 per cent of gross value of ore produced. | | |

| CONCENTRATION | |
|---|--------|
| Ore milled, tons..... | 37,556 |
| Silver content, oz. silver per ton..... | 13.53 |
| Concentrates produced, tons..... | 950.14 |
| Silver content, oz. silver per ton..... | 460 |

| | |
|---------------------------------------|------|
| Cost of milling, dollars per ton..... | 2.73 |
| Average tonnage for 313 days..... | 120 |
| Ratio of concentration..... | 39.5 |

The picking and jigging plants at the mines produced 292,886 oz. silver in jig concentrates which was added to the high-grade ore. The rock on the dumps at mines amounts to 91,857 tons, estimated to contain about 15 oz. silver per ton.

The Anaconda Copper Mining Co. reports on its operations for 1913 as follows: Severe weather in January and February, 1913, caused a diminution in the quantity of ore treated, and this, combined with the necessity of a shut-down at the Washoe smelter in October for the purpose of cleaning flues, resulted in a lessened output of refined copper for the year, as well as an increased cost for the same. The company's mines produced 4,644,201 tons of ore and 7243 tons of precipitates. The reduction works treated 4,016,689 tons of ore and cupriferous material at Anaconda, and 1,170,150 tons at Great Falls. Production at these plants was as follows:

| | Copper, lb. | Silver, oz. | Gold, oz. |
|-------------------|-------------|-------------|-----------|
| Anaconda | 205,730,594 | 9,026,690 | 53,935 |
| Great Falls | 64,571,050 | 1,294,606 | 10,964 |

The experimental work on slime concentration has been finished and plans have been adopted. Centrifugal concentration has been abandoned in favor of treatment on round tables. A plant of 2,000 tons daily capacity is under construction, comprising a slime dewatering plant of 160 Dorr thickeners, a round-table plant of twenty round tables of twenty decks each, and a concentrate dewatering plant of five Dorr thickeners. It is expected that this equipment will be ready for operation this summer, and will produce about 300 tons of concentrates daily, yielding about 1,000,000 pounds of copper per month at a very low cost. Experimental work with the 80-ton sand-leaching plant was successful, and there is now under construction a 2,000-ton plant. Further experimentation has been authorized on slime tailings. Coal-dust firing of reverberatories is under trial, following an investigation of this practice at different places in this country and Canada. The reconstruction of the smelting plant at Great Falls is progressing nicely. It is the intention to abandon the concentration of ore at Great Falls, doing all this work at Anaconda and shipping concentrates to Great Falls for smelting.

The American Zinc, Lead & Smelting Co. reports that in 1913 the zinc industry was in an extremely unsatisfactory state, and as a result of unfavorable conditions the company sustained a loss from operations amounting to \$91,656. This was augmented by other items, including one dividend of \$85,600, to a total loss, charged against surplus, of \$304,630. The physical condition of the company's smelters and other plants is good, and with a return to normal conditions in the zinc industry will be able to show substantial earnings. The new smelter at Hillsboro has made no profit, owing largely to starting under the unfavorable conditions mentioned. The Tennessee property is proving highly satisfactory, an important feature being that the tailings from the mines can be used for railroad ballast, road construction, concrete work and roofing material. The fine slime can be sold for limeing the soil of farms in Tennessee and surrounding states. This disposal of tailings may expand to such an extent as to amortize a large part of the original cost of property and equipment.

The eighth annual report of the United States Smelting, Refining & Mining Co. shows the following production of metals in 1913:

| | | Per cent of total value | Average price received |
|--------|----------------|----------------------------|---------------------------|
| Copper | 20,239,973 lb. | 18.8 | \$0.15433 per lb. |
| Lead | 58,116,504 lb. | 15.3 | .04396 per lb. |
| Silver | 13,089,708 oz. | 47.3 | .60503 per oz. |
| Gold | 148,372 oz. | 18.6 | |

Net earnings for the year amounted to \$3,585,586, and dividends totalled \$2,755,466. The report of the exploration department shows that the company was tendered 614 properties during the year, of which 490 were rejected on office examination of reports and data submitted. A preliminary field examination was made of 100, and a complete examination and sampling of 24 was undertaken. Three groups of claims were bought: the Last Chance, adjoining company property at Bingham, Utah; La Reunion group connecting the Real del Monte and Pachuca properties in Mexico, and the Spread Eagle group in Shasta county, California.

The Iron and Steel Market

For the first time since January there has been a definite and important improvement in the iron and steel market. Beginning approximately with the first of June pig iron buying increased and the volume of steel orders improved.

In pig iron the movement was largely seasonal in that the contracts of consumers began to run out and as prices were attractively low there was a disposition to cover for third quarter requirements.

In steel there had been only desultory buying for several months. While buyers probably accumulated some stocks as a result of the January buying movement, in April and May they followed a steadfast policy of reducing stocks to the utmost.

Orders for prompt shipment of steel products booked in June probably averaged between 25 and 40 per cent more than the corresponding bookings in May, which was easily the poorest month in this respect since December. It did not follow that production and shipments increased in like measure, because some of the shipments in May were the result of earlier commitments and some increase in buying was necessary merely in order that buyers should continue to receive as much material as formerly. There was, however, an excess, whereby mill shipments have probably averaged a somewhat larger tonnage in the past month than in May.

While buying for prompt shipment increased, a disposition appeared to buy for forward delivery. There had previously been scarcely any forward buying. The disposition to buy for forward delivery was partly seasonal, but it represented in larger part a recognition that prices for steel products were extremely low. In March, for instance, there was no disposition to buy for second quarter shipment as a whole, because prices had advanced not long before and were then showing a declining tendency.

With bars, plates and shapes available at 1.10c. black sheets at 1.80c. and galvanized sheets at 2.75c., all for prompt shipment, buyers began to negotiate for third quarter contracts at these figures. In practically all instances the mills quoted higher prices, by \$1 or \$2 a ton, and the third quarter business closed has been chiefly at advances of about a dollar a ton over what could be done for immediate shipment.

The present prices are extremely low relative to the cost of production. It will be recalled that a very low point was reached in November, 1911, the lowest average since early in 1899, when conditions were so different that reasonable comparisons cannot possibly be made. The average price of finished steel products

to-day is not as much as a dollar a ton above the low level of two and a half years ago. At that time the mills made practically no money. Since then the general wage level has been advanced and with mills operating at a lower rate than then their cost of production is automatically increased.

The June improvement in buying is not in itself of much significance. Early in April it began to be said that steel market conditions had become so bad that there could be no change except an improvement. The June movement in itself has not been as pronounced as was that of last January, and yet that movement played out, leaving no lasting effect. The present movement is lesser in degree and if it is similar in kind it gives no particular promise. In some quarters it is maintained that this is the beginning of a long and important movement and that the market will not soon again see such stagnation as characterized April and May. The test of the theory will come quickly. July is normally a very dull month, and if the market resists its soporific influence it will prove that there are still better things to come month by month.

The United States Steel Corporation's unfilled orders decreased 376,757 tons in April and 278,908 tons in May, leaving the unfilled tonnage at the beginning of June 3,998,160 tons, of which tonnage it is to be presumed only a relatively small proportion was for shipment within the month. Conditions in June have been such that there is a prospect that the report to be made public July 10 will show an increase for the month in the unfilled tonnage.

Steel production and shipments during June have been at fully 60 per cent of the entire mill capacity, showing no important change from May. In July many mills will close for repairs and shipments are not at all likely to increase.

Car buying was slightly heavier in June than in May. In the first half of the year fully 60,000 freight cars were ordered and this is really a fairly good showing considering what drastic policies of retrenchment are in force with the railroads.

Pig Iron

Early in June the leading cast iron pipe interest purchased 67,000 tons of Southern pig iron for second half delivery, while export orders for about 40,000 tons of Southern iron were closed at about the same time. The business developed a lower market price in Southern iron by 25 cents a ton, but at the same time greatly increased interest in the pig iron market in general. It is normal for Southern iron to lead the general pig iron market, in both upward and downward movements. Buying of pig iron has since been more general in all districts, though the movement is by no means as pronounced as was that of a year ago when conditions in pig iron were more or less similar to those of the present. Production of pig iron has been at the rate of about 24,000,000 tons a year in June, comparing with the maximum rate of this year of 28,000,000 tons, reached in March and April, and a record high rate of 34,000,000 tons, reached in February, 1913. The market is quotable as follows: No. 2 foundry, f.o.b. Birmingham, \$10.25; delivered Philadelphia, \$14.50 to \$14.75; f.o.b. furnace, Buffalo, \$12.75 to \$13; f.o.b. furnace, Chicago, \$13.50 to \$14; at valley furnaces (90 cents higher delivered Pittsburgh) No. 2 foundry, \$13; basic, \$13; malleable, \$13 to \$13.25; gray forge, \$12.50 to \$12.75; Bessemer, \$14.

Steel

As a rule, consumers of billets and sheet bars did not absorb their full contract tonnages in the second

quarter and with considerable tonnages being carried over July 1 they have been slow to negotiate fresh contracts. While little has occurred to develop actual market prices it is recognized that the market is quotable at about \$19.50 for billets and \$20.50 for sheet bars, f.o.b. makers' mill, Pittsburgh or Youngstown, these prices being 50 cents a ton below the nominal figures named a month ago.

Rods can be had at \$25, mill, or \$1 a ton below the quotation of a month ago.

Finished Steel

Prices quoted below show a slight decline, on the whole, during the month. They are for prompt shipment, contracts covering a period of three months usually bringing about \$1 a ton more. Quotations are f.o.b. Pittsburgh, unless otherwise noted:

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.10c.

Steel bars, 1.10c., base.

Shapes, 1.10c.

Iron bars, 1.25c., Pittsburgh; 1.22½c., Philadelphia; 1.05c., Chicago.

Sheets, blue annealed, 10 gage, 1.30c.; black, 28 gage, 1.80c.; galvanized, 28 gage, 2.75c.; painted corrugated, 28 gage, 2.00c.; galvanized corrugated, 28 gage, 2.80c.

Steel pipe, ¾ to 3-in., 80 per cent off list.

Steel boiler tubes, 3½ to 4½ in., 72 per cent off list.

Standard railroad spikes, 1.40c., Pittsburgh; 1.50c., Chicago.

Structural rivets, 1.55c.

Boiler rivets, 1.65c.

Cold rolled shafting, 66 per cent off list.

Chain, ¾-in. proof coil, 3.00c.

The Non-Ferrous Metal Market

During the past month the non-ferrous metal market has been dull, with comparatively little business transacted. Lead has proved strongest, showing larger sales and a good future inquiry. Tin has been unsteady and at times panicky. Spelter is dull and without feature.

Copper.—Prices have tended toward weakness and sellers have offered inducements to the trade. At the low level of prices buyers are showing some interest, but are not yet buying heavily. Electrolytic copper is quoted at 13.7 cents, New York. Sales of Lake are reported at 14@14¼ cents.

Lead.—This is the most active of the metals and fair sales are reported. Some small sales have been made for export. The market is steady at 3.90 cents, New York, and 3.82½ cents, St. Louis.

Tin.—The domestic market has been marked by fluctuations in prices, and the London market has been sensitive.

The latest quotation for June tin is about 31½ cents, New York.

Spelter.—Somewhat lower prices have prevailed in this market. Buying is slack and consumers have exhibited little interest. New York spelter is quoted at 5@5.05 cents, and St. Louis 4.85@4.90.

Other Metals.—Business in aluminium is quiet and orders are scarce. No. 1 ingots are quoted at 17½@18 cents, New York. Antimony is not specially active and various brands are quoted at 5.75@7.35 cents. A fair business has been done in quicksilver, the New York quotation being \$37.50@\$38.50 per flask of 75 lb.

San Francisco quotes \$37 per flask for domestic orders and \$2 less for export.

Troy Meeting of the American Institute of Chemical Engineers

The sixth semi-annual meeting of the American Institute of Chemical Engineers was held in Troy, N. Y., June 17 to June 20. The meeting was opened at the Pittsburgh Building of the Rensselaer Polytechnic Institute by an address of welcome by Hon. C. F. Burns, Mayor of Troy, followed by an address by President Ricketts of the Rensselaer Polytechnic Institute, in which he referred to the rapid growth of the chemical engineering profession and the development of chemical engineering courses at the Rensselaer Polytechnic Institute and other technical institutes and universities.

The reports of the various committees and officers of the Institute were then presented. The Secretary reported a steady gain in membership which at present is 214. The Treasurer's report showed a substantial balance in the treasury. The Committee on the Standard Chemical Engineering Catalogue reported progress in drafting specifications for the Catalogue.

The following papers were then read: Mr. W. F. Rittman presented a paper on the Applications of Physical Chemistry to Industrial Processes and showed how problems in the manufacture of sulphuric acid, illuminating gas and the fixation of atmospheric nitrogen could be solved by physico-chemical methods. This paper is published in full on page 475.

Prof. J. W. Bain and Mr. A. E. Wigle presented a paper on Filtration, in which they showed the efficiency of filtration and washing of solids under various conditions. It was shown that the amount of liquid remaining in a solid was independent of the size of the particles but varied with the pressure.

Prof. Chas. Boskerville described a very efficient scrubber for vacuum apparatus for laboratories.

Luncheon was then served to the members of the institute by the Rensselaer Polytechnic Institute.

The U. S. Arsenal at Watervliet, N. Y., was visited Wednesday afternoon under the guidance of Colonel Gibson. The shrinking on of the outer jacket of a 14-in. coast-defense gun was witnessed as well as the very interesting operations of rifling the guns and winding guns with rectangular steel wire.

The testing laboratories and buildings of the Rensselaer Polytechnic Institute as well as the gymnasium building and swimming pool were then inspected.

After an informal dinner at the Hotel Rensselaer President Whitaker delivered an address in which he urged the desirability of greater publicity of the experience gained in chemical plants, especially with reference to failures of installations, disastrous accidents and explosions. Great benefit would result to the chemical engineering profession and chemical industries without the losses which would be involved in the publication of the details of successful processes. The address is printed in full on page 437.

Dr. L. J. Matos read a paper on shoddy and carbonized waste showing the methods by which woolen fibre is recovered from rags containing cotton and made available for spinning and weaving. The great economy of this utilization of waste material was emphasized especially in view of the shortage of raw wool. The superiority of much of this recovered wool to many grades of raw wool was shown. The impossibility of distinguishing, in the finished fabric, between raw and recovered wool was also explained. The length of the fibre cannot be used as a test because various grades of the raw wool contain both long and short fibres.

Prof. Wm. P. Mason then showed a number of lantern slides of the Saratoga septic tanks and explained

their operation and also discussed a remarkable explosion of one of these tanks, the cause of which has not been clearly demonstrated. Professor Mason suggested the possibility of the combustible gases produced by the bacterial action having been ignited by phosphine produced by the same action.

On Thursday the plant of the General Electric Company at Schenectady was visited. The entire process of manufacture of dynamos and steam turbines was inspected. Special interest was shown in the mercury-vapor engine in course of development, which shows an efficiency 50 per cent higher than the ordinary steam engine. The new Research Laboratories were also inspected, after which lunch was served by the General Electric Co.

The members then proceeded by a special private car of the Schenectady R. R. Co. to Saratoga, where they were shown the springs and the state reservations by the resident physicians who furnished their automobiles for the purpose. After inspection of the sewage disposal plant the return trip to Troy was made in the special car.

In the evening the members took dinner at the Troy Club, after which addresses were made by President M. C. Whitaker, Prof. Wm. P. Mason, Dr. Chas. Ferris of the State Reservation Commission, Prof. Edmond O'Neil of the University of California, Prof. James R. Withrow, Prof. A. M. Green of the Rensselaer Polytechnic Institute and Secretary Olsen. Prof. O'Neil extended an invitation to the Institute to meet in San Francisco in September, 1915.

At the meeting Friday morning at the Hotel Rensselaer, Professor Withrow reported that the Committee on Chemical Engineering Education is cooperating with the Carnegie Foundation in its investigation of the chemical engineering courses given in American colleges and universities and that the Carnegie Foundation has engaged Dr. C. R. Mann to inspect the institutions giving such courses.

The following papers were then read: Mr. John C. Hebden gave the results of a careful study of the chemistry of the bleaching of cotton fibre. He presented analyses giving the composition of the raw cotton as well as its composition after each of the processes of cleaning, bleaching and washing.

Dr. J. C. Olsen and Mr. Wm. H. Ulrich reported the results of experiments showing that ozone oxidizes many substances producing odors, and pointed out many serious errors in the article by Jordan and Carlson on Ozone.

Mr. Maximillian Toch, in a paper on the present patent situation, showed that the new rules for the taking of evidence in patent litigation are not being observed on account of the failure of the United States Government to provide a sufficient number of judges to hear patent cases. Dr. M. H. Iltner also read a paper on patent abuses.

On Friday afternoon the manufacture of collars and shirts was inspected at the factory of Geo. P. Ide & Co. The plant of the West Virginia Pulp and Paper Co. at Mechanicsville was then visited, where both the sulphite and the soda process as well as the electrolytic production of soda and bleach liquor were shown.

Friday evening Mr. L. M. Booth presented a paper, illustrated with lantern slides, on a combination water softener and storage tank. In this installation the calcium and magnesium salts are rapidly precipitated by chemical treatment and mechanical agitation while the clear, softened water is taken off at a suitable height above the sludge. Filtration is thus rendered unnecessary. By making the tank of a sufficient size storage is provided for.

Mr. Richard K. Meade presented a paper giving the developments of the rotary furnace and suggested a number of new applications for this type of furnace. Numerous lantern slides were shown.

The members were entertained at a smoker at the residence of Dr. Wm. P. Mason and were given the opportunity of meeting President Ricketts of the Rensselaer Polytechnic Institute.

On Saturday the plant of the Burden Iron Works was visited where the puddling process for wrought-iron was shown. The attendance at the whole meeting was excellent.

The winter meeting of the Institute will be held in Philadelphia early in December. Dr. John C. Olsen, Polytechnic Institute, Brooklyn, N. Y., is the secretary of the Institute.

Ninth International Congress of Applied Chemistry

The Executive Committee of the Ninth International Congress of Applied Chemistry, to be held in St. Petersburg, Russia, in 1915, has just issued its first Preliminary Announcement.

The Congress will open on July 26-August 8, and close on August 1-14, the second dates in each case being the dates in the new-style calendar. That is, according to the calendar in use in the United States the Congress will be held* from August 8 to 14, 1915.

The Emperor of Russia will be the Patron of the Congress. D. P. Konovaloff, Assistant Minister of Trade and Commerce, will be the Honorary President. Professor P. I. Walden will be the President. Major-General Professor W. N. Ipatiew will be the Honorary Secretary.

All letters are to be addressed to the Honorary Secretary, Ninth International Congress of Applied Chemistry, Winter Palace Place 8, St. Petersburg, Russia (cable address Chimicongress, St. Petersburg).

The membership fee is ten roubles (equivalent to about five dollars), payable in postal money order or check on a St. Petersburg bank, to the Treasurer of the Congress, V. T. Schaefer, whose address is also Winter Palace Place 8, St. Petersburg.

Applications for membership must contain the applicant's full name, exact address, profession and name of Section or Subsection in which he wishes to take part.

Membership fee must be paid not later than April 1, 1915, if delivery of the printed Transactions is to be guaranteed. The printing of papers will begin in April, 1915, and the size of the edition will depend upon the number of membership fees received on or before April 1-14, 1915.

Ladies accompanying members of the Congress may receive tickets upon the payment of seven roubles. These tickets entitle them to all rights of the Congress with the exception of the right of participating in debates and administrative affairs. Such tickets do not entitle the owner to receive the printed Transactions of the Congress.

"To insure free passage into Russia for all members as well as for ladies accompanying them it is necessary to show at the frontier, in addition to passports with visa, membership cards, signed by the President and Honorary Secretary of the Congress." (In the *Percolator* the same statement is expressed as follows: No obstacles will be placed in the way of the journey of Jewish chemists to the Congress provided that at the

*In the *Percolator* of the Chemists Club of New York of June 18 it is stated that the Congress will be held from August 20 to 26, 1915. This statement is based on the authority of a letter of President Walden of Feb. 20, 1914. We are unable to explain this discrepancy of the dates, but assume that the correct dates are April 8 to 14, as stated in the official Preliminary Announcement, just issued.

frontier, in addition to the vised passport (requisite for every passenger), cards of membership, signed by the President and Honorary Secretary of the IX International Congress shall have been presented.)

The official languages of the Congress shall be Russian, French, English, German and Italian.

The list of the 22 sections and subsections is as follows: 1. Analytical Chemistry. 2. Inorganic Chemistry. 3. Metallurgy and Mining. 3b. Explosives. 3c. Ceramic and Glass. 4. Organic Chemistry. 4a. Colors. 5a. Sugars. 5b. India Rubber and other Plastics. 5c. Fuels and Asphalt. 5d. Fats, Fatty Oils, Soaps and Drying Oils. 6a. Starch, Cellulose and Paper. 6b. Fermentation. 7. Agricultural Chemistry. 8a. Hygiene. 8b. Pharmaceutical Chemistry and Pharmacology. 8c. Chemistry of Foods; Physiological Chemistry. 9. Photochemistry. 10a. Electrochemistry. 10b. Physical Chemistry. 11a. Legislation relating to Chemical Industry. 11b. Political Economy and Conservation of Natural Resources. (The only essential difference from the arrangement of the sections at the Congress in New York City, 1912, is that the former subsections 5e. and 8d. have been abolished and combined with other sections.)

Paris Meeting of the British Iron and Steel Institute

The autumn meeting of the (British) Iron and Steel Institute will be held in Paris on Thursday, Friday and Saturday, Sept. 17, 18 and 19. On the conclusion of the meeting in Paris a visit will be made to Nancy and to the principal iron mines and metallurgical works of French Lorraine.

The meetings in Paris will be held in the House of the Comité des Forges, Rue de Madrid, Paris.

Mr. G. C. Lloyd, 28 Victoria Street, London, S. W., is the secretary of the Institute.

A Mine at the Panama-Pacific Exposition in San Francisco, 1915

The U. S. Bureau of Mines has undertaken to construct, in cooperation with the mining industry and the manufacturers of mining machinery, a mine beneath the floor of the Palace of Mines and Metallurgy at the Panama-Pacific Exposition.

Typical metal and coal mining operations will be reproduced by full-size working places in which mining machinery will be installed and operated. The walls of the mine will be covered with either ore or coal typical of the mine illustrated. Among others, the Copper Queen Consolidated of Arizona, Bunker Hill Sullivan Company of Idaho, Homestake Mining Company of South Dakota, Goldfield Consolidated Mines company of Nevada, Jones and Laughlin Company of Michigan, Lehigh Coal & Navigation Company of the anthracite field of Pennsylvania, Pocahontas Fuel Company of West Virginia, Consolidation Coal Company of Kentucky, and Pacific Coast Coal Company of Washington, have each agreed to reproduce one of their working places or stopes and to contribute the sum necessary to the installation and operation. Tentative promises of similar action have been received from the Rock Island Coal Company, Peabody Coal Company, and Pittsburgh Coal Company.

Various mining machinery and appliances have been promised, including a mine cage and cars by the Joshua Hendy Company; a cage, hoist and motor by the Denver Engineering Works; locomotives by the Westinghouse Electric & Manufacturing Company; pumps by Byron Jackson; air compressor, drills, drill sharpener and winze hoist by the Compressed Air Machinery Com-

pany; drills and coal cutters by the Ingersoll Rand Company and the Sullivan Machinery Company; lamps by the Justrite Manufacturing Company and the Koehler Manufacturing Company; enamel signs by Stonehouse Enamel Sign Company.

The entrance to the mine will be through the Bureau of Mines space, and visitors will be attracted to it by being given portable mine lamps, and by being lowered in a very slowly moving cage while a panoramic effect of the strata lining a mine shaft will pass by them so rapidly as to produce the illusion of descending to a considerable depth. In case of crowds, these may enter by a slope. Exit will be by a slope into the radium booths of the Bureau of Mines where radium emanations will be shown.

There will be a motion-picture room which visitors will pass in going from mine to mine. In it will be shown such great open workings as are not illustrated by the underground mines, such as those of the Utah Copper Company and those of the Nevada Consolidated Company at Ely, the iron diggings at Hibbing, Minn., hydraulic gold mining, and the quarrying of building stone.

Twice each day there will be an imaginary explosion or fire in some portion of the mine announced by telephone to the superintendent's office in the Bureau of Mines space on the surface, and rescue men wearing breathing apparatus will enter the mine and bring out supposed victims who will be given first aid treatment in the surface emergency hospital.

In the Bureau of Mines space on the floor of the main building, there will be, in addition to the radium booths, exhibits of carnotite, pitchblende and other radium ores, their alloys and concentrates, an emergency mine hospital and smoke room for rescue training, exhibits of fuel efficiency, smoke abatement, explosives, mine welfare work, etc.

The prime purpose of the mines will be that of educating the investing public, stockholders, members of legislatures and the uninformed antagonists of the industry relative to the importance of the mining industry, its extent, variety and the cost of operation.

Electric Hoists of one-ton or two-ton capacity are the subject of Bulletin 301A of the Pawling & Harnischfeger Co., Milwaukee, Wis. The system here described should be particularly attractive for such industrial plants in which hand labor is still employed for lifting loads and carrying them over short distances. In such plants an electric hoist with 200 or 300 feet of runway will in most cases pay for itself inside of a few months as it will replace from three to ten men, depending on conditions, and can be easily and quickly installed. The design in question is an overhead monorail hoist, traveling on the lower flanges of an I-beam. The illustrations in the bulletin show the application of this hoist for lifting heavy paper rolls in a printing shop, for handling pipes, rods and plates in steel works, for carrying boxes in a warehouse, etc. When the hoist is equipped with electromagnets for handling iron bars, plates, etc., the operator handles the load alone without other help. Another illustration shows the very complete monorail system with turntables, crossovers, switches, etc., installed at the International Harvester Co.'s plant at Milwaukee, Wis.

Calendar—"Again we say what is so rare as a day in June for a new calendar?" The Wagner Electric Company of St. Louis, Mo., has issued a very attractive calendar, covering the period from June, 1914, to May, 1915. The picture on the calendar is that of a little boy in quiet but evident admiration of a little motor.

Some Professional Obligations*

BY M. C. WHITAKER

Chemical engineering as an organized profession is comparatively new, although many men have been engaged in this class of work since the beginning of large-scale manufacture. Since the organization of this Institute, various definitions have been given to outline the scope of our professional activities, many schemes have been suggested to improve the training of our apprentices, some advances have been made towards standardization in our engineering practice, a code defining the ethical standards of our profession has been formulated and adopted, and we have shown our aims, with some results, in constructive patent reform.

Work of such a character is of the greatest importance, and is far in advance of that heretofore undertaken by any other organization in our field. It can never be regarded as completed, and the best thought and effort of well constituted committees will continue to be given to advancement along these lines, with great resultant benefit to the profession.

There comes a time, however, in the life history of every organization or enterprise when the greatest advancement and improvement may be made by a process of introspection. It would seem to the speaker that chemical engineers might now, with great profit to themselves and benefit to the profession, submit to a process of self-analysis. Obviously it would be out of time and place to attempt now a profound or philosophical analysis of our internal personal relations and aims, but it is hoped that by reference to a few of the more fundamental points we may thereby catalyze some productive reactions.

Chemical engineering must, sooner or later, come to be recognized as the leader among the engineering professions. Its interests are larger and more varied, and its scope is greater and more intimately related to social and industrial progress than that of any one or all of the other branches of applied science. Manufacturing output in the United States, which in money value is already almost equal to the largest single productive interest, will be dependent in some, if not in all, of its steps upon the chemical engineer. The burden of the development of the industrial processes and the operation of the plants will fall upon him, and naturally the rewards of success and the odium of the failures will be his. The realization of the opportunities of such a profession, so full of brilliant promise and great possibilities, will depend in a large measure upon the breadth of view adopted in the acceptance of our responsibilities.

A voluble assertion of our importance will not give us the power to master our calling. Professional prestige, in the engineering field at least, is built upon achievement. Achievement worthy of the dignity of a profession cannot be built upon independent work, the spectacular results of a few individuals or the hit-and-miss strokes of fortune. It must be based upon a consistent development of and by a body of able progressive men, and be based upon years of unselfish constructive co-operation, in which each member contributes his share, and in turn, draws freely from the common store.

The legal, the medical and the clerical professions have devised for themselves some form of legal protection. The engineering professions, on the other hand, are subject to no form of external control, and may become self-developing or self-effacing according to the wisdom of the policies adopted in their direction and development, and the positiveness and value of

their achievements. Merit, after all, is the only measure of success in engineering, and all failures, and even doubtful results, are promptly charged off against the profession.

The civil engineer may design and build a bridge. During construction his work is open and in full view of the public and his colleagues. There is not a single feature of his purpose, his design or his materials of construction which is not common knowledge to anyone who takes the trouble to look at his work, or read any of the numerous articles published during its progress. Even the lay public may be interested and pay their tribute to the man behind the work. The finished bridge stands in public as a monument to the power and ability of the builder and the profession he represents.

The mechanical engineer may design and build a wonderful machine. There is no secret about any of the features. His colleagues, the public, or anyone may study and criticize his work, accept and profit by his suggestions and ingenious features, or may avoid his mistakes. The mechanical engineer has profited by the successes and failures of his predecessors in the art, and his successors, in their turn, will build better as a result of his work.

So it is with the mining and the electrical engineer. Each works with a full knowledge of what has gone before; each contributes his share to the advancement of his art, and the standing of the professions is enhanced because of his contributions.

The chemical engineer, on the other hand, works in unappreciated silence behind factory walls. He is not building a monument which invites public approval, though he may be making a product of equal value and more wonderful if it were understood. The details of his work are carefully guarded, and he is even denied the stimulus of public interest in his achievements. His designs, materials and methods often lack the helpful suggestions of his fellow engineers. He may repeat at great expense the mistakes previously made by his neighbor, or may fail to avail himself of well worked out methods which are unknown to him on account of lack of proper exchange of professional knowledge.

If he is secretive it comes as a result of environment and conditions. This secretiveness often becomes a habit and is assumed to be a necessity. At times this habit is extended either unconsciously or accidentally to ludicrous limits.

For example, note how difficult it is to find the professional or business connections of a chemist or chemical engineer. Surely there is nothing about this which should be concealed. On the contrary, good would result both to him and his employer by having his connections and field of activity well known. The directories of all other engineering societies contain valuable information about the professional activities of their membership, while our directories in many cases carefully disguise even the business addresses of our members.

The chemical engineer's efficiency in the production of successful results is reduced to a minimum, because of a lack of liberal professional co-operation, while civil, mechanical, electrical and other engineers are steadily improving their professional efficiency by a systematic exchange of principles and practices, and a selective action to carry forward the good methods and reject the bad ones. We of the chemical engineering profession are harboring conditions which retard or frequently even prevent professional progress.

When the work of the chemical engineer is not open to public view, his productive efforts not understood, and therefore not appreciated, his achievements cautiously guarded, his business connections withheld from the directories of his societies and absolutely no record

*Presidential address delivered before the American Institute of Chemical Engineers on June 17, 1914.

of his professional activities is made available, is it any wonder the lay public usually think of him as a druggist?

If one traces the life history of the development of the chemical engineer, it will be found that we have some bad traditions to overcome. Our alchemist forefathers cultivated secretiveness, mystery, and even deception. These dark-art traditions are openly professed to-day in some of our factories, while in others they remain in latent evidence.

With these adverse conditions and traditions in existence it would seem that the chemical engineers are confronted with an important problem which intimately concerns the progress and development of the profession. Inefficiency and loss of prestige are bound to result from unsupported individual effort. Co-operation is essential to substantial engineering development. This co-operation comes about naturally in other engineering professions, and it will have to come, if not naturally then by force of necessity, in ours.

Every failure in design, every fatal accident, every industrial disease, every fire or explosion in a chemical works, every commercial insuccess is an indictment against the chemical engineering profession. Cause and effect in bridge failures, dam failures, boiler explosions, railroad and steamship wrecks, are freely discussed in conventions and journals for the benefit of the interested profession. These open and frank discussions disarm public criticism on the one hand, and on the other place before all members of the profession most impressive and profitable lessons in what not to do.

The chemical engineer in such cases, apparently guided by his ancient traditions, or his environment controlled habits, as no other motive seems discernible, often secretes the facts not only from the public but also from his professional associates. Such secretiveness always arouses public suspicion. The interests of humanity may be sacrificed, and the profession, without the knowledge of what has happened, may go blundering into the same disaster again and again. These costly disasters are not even recorded as experience outside of the factory walls in which they occur.

Have the chemical engineers discussed or even heard of the causes leading to the failure of the coke plant at Bethlehem; the cause and effect of the explosion in the artificial leather factory at Detroit; the lessons to be drawn from the recent fire in the Mallinckrodt works in St. Louis; the cause and effect of the failure of a large gas holder at Philadelphia; the cause or remedy of the large number of industrial diseases in some of our plants; the complete failure of this or that piece of equipment or method of installation?

Do the affected or afflicted chemical engineers seek the assistance of their associates and professional colleagues in determining the cause, and suggesting the remedy for such disasters? If the cause and the remedy are determined, are the facts made public?

Think of the benefit which would come to our profession and to humanity and industry in general from frank authoritative discussion of these and many other problems which come within the experience of every chemical engineer. The discussion of the defective design, or material, or installation of chemical engineering appliances is a thing which would be of inestimable benefit, not only to other engineers, but also ultimately to the producers of the appliances. Negative results can be of no possible value to those industries which have developed them, but if they were published or discussed they would become of the greatest importance to future engineering progress. Why should they be jealously guarded and secreted and the progress of this profession thereby blocked?

The question as to what knowledge the manufacturer should disclose for public use and what should be kept within the factory walls is one which may be settled by the rule of reason, but never settled by yielding to the inclinations of our natural environment and our ancestral traditions. When it becomes clear that these conditions are blockading engineering progress and our own professional development, it will not be simply a duty, but an obligation, for every chemical engineer to apply this rule of reason.

Property value might safely be accepted as the basis for determining what should and what should not be disclosed. Manufacturers and chemical engineers would not be expected to give out unprotected information of direct property value any more than civil engineers would be expected to publish their working drawings before the contracts were awarded, or the mechanical engineer be expected to give away the appliances in which he had invested his time and his money. Such a policy would result in commercial anarchy and tend to destroy industrial stability and with it the dependent professions.

Fortunately it is very often the knowledge having the least property value which, when collected and classified, possesses the greatest professional value. Negative results can usually be disclosed without loss and they form the most substantial basis for engineering development.

On the other hand, the publication of the failure of a design, a material or a process would invite constructive thought from others which might turn a failure into a success, or suggest to our young investigators researches which would definitely establish or disprove the scientific validity of the principles involved.

The interests of humanity demand that industrial diseases, industrial accidents and improvements in working conditions be openly and frankly discussed in order that the combined effort of all minds be brought to bear on the needed solutions. Proper publicity in all bad or doubtful cases would do much to soften the hearts of the financial control, and at the same time independently enlist the services of the physiological chemists, the medical researchers, the mill designers and many minds in our own profession which is most seriously indicated.

We have all heard the statement by members of this profession that there are no adequate textbooks or handbooks in chemical engineering of the same standard of excellence as those existing in mechanical engineering, for example. Such books, in any engineering field, are the results of compilations and classifications of approved matter from current technical journals and society proceedings, and it is inevitable that they will be large or small, dense or rare, profound or superficial, in direct proportion to the current available material.

If we secrete our information, or fail to publish our researches, hoard our knowledge and avoid the full and frank discussion of our industrial problems, we are bound to reap the negative rewards. Our books will not represent the sum of a profession's knowledge, but instead the comparatively small, laboriously attained work of one or a very few individuals.

This institute, representing as it does the leading organization devoted exclusively to developing the technical interests of the chemical engineers, and enhancing the prestige and value of that profession, should be the first to consider all obstacles to the accomplishment of its purpose. Our profession is built upon the applications of a science of the most infinite and varied detail. The mastery of modern chemistry requires a highly developed mind and one which should be fully qualified to attack and solve with ease the problems of policy in the development of the profession.

Our organization is new and the problems are large and numerous. Most careful consideration must be given to the direction of our energies into those channels in which we shall find the most productive returns. We have no time to waste on philosophical quibbling or fussy arguments. If self-analysis shows that the indictment of narrowness is valid and that the best interests of our profession will be served, as I think they will, by a more active interest in public questions, such as the so-called conservation movement, public service control, corporate regulation, financing of industrial enterprises, etc., then we should study and discuss these problems in our meetings and proceedings.

If chemical engineering education is twenty or thirty years behind the methods and efficiency of mechanical and electrical engineering training, as I think it is, and its improvement is being blocked by the dogmatic teaching that chemical manufacture is nothing more than enlarged laboratory practice, it then becomes evident that even more strenuous efforts will be required from this institute and its hard working committees to produce the desired results.

If, as I firmly believe, our professional progress is being seriously blocked by an unjustified and unjustifiable veil of secrecy or mystery drawn around our experiences, our needs, our achievements and our professional activities, the removal of this obstacle to our advancement becomes an obligation upon each constituent member of the chemical engineering profession, and particularly upon the Institute of Chemical Engineers.

Chemical Engineering Laboratories,
Columbia University, New York.

Physical Versus Chemical Actions in Furnaces

BY CARL HERING

In many furnace processes, aside from simple melting, there are often both chemical and physical changes which either consume or set free energy, hence must be considered in processes in which the cost of the electric energy is of importance.

In books the energy involved in a chemical change or reaction, and generally though erroneously called "heat" of combination, is given in a lump sum regardless of how much of it is for the purely chemical part of the total and how much for the physical parts which may be involved in the change. By a chemical change is here meant a rearrangement of the atoms which results in a different chemical compound or product; by a physical one is meant a change of state of any parts of the material, say from solid to liquid or gas, or to a solution in a solvent, or a change of temperature, etc., hence it includes all changes other than the chemical ones.

For instance, when Fe_2O_3 is combined with C in a pig-iron blast furnace, the chemical changes are the reduction of the iron oxide and the oxidation of the carbon; while the physical changes are the liquefaction of the solid iron and the vaporization of the solid O and the solid C into a gas, hence involving an enormous expansion against atmospheric pressure (about 7000 to 8000 fold) and the latent heats of both fusion and vaporization of C and O.

In books the energies involved in these various changes are jumbled together into one amount. The object of the present note is to call attention to the desirability of separating them into their component parts, at least for electric furnace processes in which the energy consumption is important; by thus separating the parts of the whole into the chemical and the physical energies, it may sometimes be found to be cheaper to do the physical part by other means than by electric heat

or it might be possible to prevent an energy consuming physical change from taking place, or perhaps even bring about an energy producing one; the purely chemical changes might perhaps also be facilitated in such ways.

When we know how much of the energy involved in a furnace process is physical and how much is purely chemical, it becomes possible to estimate whether that process might perhaps be cheapened by saving some of the energy involved in the physical part or by producing it more cheaply. The chemical changes, being the ones usually wanted, cannot of course be avoided, but even the energy involved in these purely chemical reactions might be modified by different physical conditions; for instance, near the temperature of the dissociation point of a chemical product the energy involved in making or breaking chemical bonds is much less, and this dissociation point might perhaps be raised or lowered as desired, by purely physical means other than heat, as for instance by pressure.

Some electric furnaces can be operated commercially at a positive or a negative pressure, and if this is an advantage, it might be possible to produce such pressures cheaply, thereby saving some of the electric heat.

If, for instance, a final product ordinarily leaves the furnace as a gas, but has entered it as a solid, as for instance in the production of zinc, arsenic, phosphorus, sulphur, etc., both the latent heats of fusion and vaporization must be supplied as electric heat, as must also the energy involved in the enormous expansion from a solid to a gas, and perhaps also the heating of this gas. But if by means of a positive pressure such a product could be kept liquefied in the furnace, and removed in that form, the energy required for these physical changes would not have to be supplied electrically to the furnace.

A negative pressure, on the other hand, might in other cases so reduce the vaporization temperature of a gas which is to be eliminated that less furnace heat would be required to accomplish its separation. Or in general, when a gas like CO or CO_2 is generated from solids and must be removed, it would consume less furnace heat to have it expand into a vacuum than against atmospheric pressure.

Numerous other cases might be cited to show the energy effect of the purely physical part of a process. Water might electrolyze easier in vacuum than if the gases must expand many hundreds of times against a pressure of 15 lb. per square inch, which consumes energy. Some of the impurities in molten steel might be more cheaply removed by a negative pressure (suction) than by chemical reactions, or than by calories alone, as in producing greater fluidity. If the oxygen in iron oxide is removed as a solid, by a solid, and the product is also a solid (or liquid), the energy for its expansion into a gas (physical) is saved; that is, there is no lowering of temperature due to this expansion; this is one of the causes of the high temperatures in the thermit reaction which is of this kind. If a gas, like hydrogen, combined with solid oxygen (in an oxide) the product being liquid water, the energy of the great contraction of the gaseous hydrogen to a liquid must be set free, hence is a gain and might perhaps be made to be available.

It is therefore thought by the writer that a clearer distinction between the physical and the chemical parts of a desired process may lead to a better understanding of what actually takes place; that is, it may give us a better mental picture, and this in turn might aid in improving or cheapening a process. Hence the writer claims that the energies of the chemical changes of compounds, or "heats" of combination as they are loosely called in books, should in future be stated in their

component parts, with a clear distinction between the chemical and the physical, the latter being again subdivided into its constituent parts; the diminution of the chemical energy with a rise of temperature should also be stated. With this detailed data it would then become possible to estimate whether it might cost less to do the physical part in some other way than by expensive electric heat, or at least to facilitate it.

When the total "heats" of combination are thus resolved into their components, the speculative thought suggests itself that perhaps some of the apparently endothermic (energy absorbing) processes which take place spontaneously are in fact exothermic as far as the purely chemical part of the process is concerned, their endothermic character being perhaps due to the physical parts of the process.

When steam is heated to increasingly high temperatures, a point will be reached at which the chemical affinity of the hydrogen and oxygen becomes zero; this is known as the dissociation point; the molecules of these elements mixed together then have little more concern for each other than black and white marbles have when mixed in a bag. Their energy of chemical combination must therefore have been supplied during this heating process, yet all the heat that was added ostensibly merely increased the temperature, hence is, according to the books, classed under specific heat. This high temperature dissociation applies not only to steam but to most other chemical combinations.

It would be hard to believe that in such a case the energy of combination which was evidently supplied while the temperature was being raised, was taken up suddenly at any one temperature, like the latent heats of fusion and volatilization are, unless there is experimental evidence to this effect. It is more than likely that the real facts are, that as the temperature of a compound is gradually raised the chemical bond is weakened more and more until it becomes zero at the dissociation point; hence at that point all the energy of combination has been supplied to the material.

If that is the case, then what we call specific heat is not entirely such for compounds, but consists of two parts, a real specific heat and a part which goes to reducing the energy of the chemical bond, a physical and a chemical part; the chemical affinity grows weaker as the physical activity increases.

The rates at which these affinities thus decrease with a rise of temperature is apparently different for different chemical combinations, hence the curves representing them may and apparently do intersect in many cases.

If this is correct, then it does not seem irrational to suppose that in raising the temperature of the iron oxide, a portion of the energy of combination of the iron and its oxygen has really been supplied under the guise of specific heat (physical), and the bond has been weakened to such an extent that at the temperature of the reaction the affinity of the carbon for the oxygen exceeds it, and in that case the chemical reaction itself would continue spontaneously, as we know it does.

As explained above, there are moreover some purely physical changes in this reaction which must also be considered in the equations representing the energy transfers, or else they will mask the real actions. The carbon and the oxygen are changed from a solid to an expanded gas. The energy for these physical changes must be supplied from some source. If not added to the system the materials may be robbed of it, which means a lowering of the temperature; hence to keep up the temperature necessary for this chemical reaction heat must be supplied as fast as the oxygen and carbon are volatilized and the iron melted.

This necessary supply of heat has probably by some

been erroneously supposed to be part of the energy of the purely chemical part of the reaction. It will readily be seen, however, that this part is purely physical and not chemical at all, though in using terms loosely the chemical and physical parts may have again been jumbled together in some books, just as the purely physical specific heats seem to have included parts of the chemical energy, as mentioned above. Carelessness in not distinguishing between the physical and the chemical parts of a process may lead to much confusion and erroneous deductions and conclusions.

Philadelphia, June, 1914.

Sulphuric acid produced at zinc and copper smelters is a factor of increasing importance in the acid industry of this country. According to figures compiled by the U. S. Geological Survey, the 1913 production from this source amounted to 790,296 short tons of 50 deg. acid, valued at \$4,346,272. Copper smelters produced slightly more than zinc smelters.

Statistics on the world's zinc industry and trade have been compiled by the Department of Commerce from information furnished by the various U. S. consuls. The following tabulation gives the output of spelter for 1913:

| Countries | 1913 Short tons. |
|---------------------------|---------------------|
| Australia | 4,105 |
| Australia and Italy | 23,856 |
| Belgium | 217,941 |
| France and Spain | 78,293 |
| Germany | 311,914 |
| Great Britain | 65,201 |
| Netherlands | 26,813 |
| Norway | 19,040 |
| Poland | 9,520 |
| United States | 346,676 |
| Total | 1,103,359 |

Gas Producers.—The Pittsburgh Plate Glass Company have just placed an order with the Chapman Engineering Company, Mt. Vernon, O., for five 10-foot inside diameter Chapman rotary gas producers. These are to be installed in their No. 11 Works, Mt. Vernon, Ohio, and supply gas for their two furnaces previously using natural gas. This is the second important installation of Chapman producers made by the Pittsburgh Plate Glass Company. The American Bottle Company are installing in their Newark, Ohio, plant one 10-foot Chapman producer to replace natural gas. This also is a second Chapman producer installation for this company. The American Clay Company, Terre Haute, Ind., have recently placed in operation one 10-foot producer, which replaces three hand-poked machines. The gas is used for burning hollow building tile in continuous kilns. The Chapman producer has reduced the coal consumption, decreased the time necessary to burn, and increased the percentage of good ware.

Reserves of zinc concentrates in the Joplin district, according to the authority of Mr. L. L. Wittich, are not acting as a bear on prices. They amount to 12,000 or 14,000 tons, the largest accumulation being 4000 tons at the Mont B mine. These concentrates cannot be bought at prevailing prices.

The value of Utah's mine output of gold, silver, copper, lead and zinc in 1913 was \$44,858,210, according to the U. S. Geological Survey. This is an increase of nearly \$2,000,000 over 1912. The silver production showed a slight decrease. There was a large increase in copper, the Bingham district producing 145,000,000 pounds. The total quantity of all ore sold or treated in the state during the year was 10,202,566 tons. The average recoverable value was \$4.39 per ton. Gold production was valued at \$3,565,229; silver amounted to 13,084,835 ounces; copper, 161,445,962 pounds; lead, 166,126,790 pounds, and zinc, 18,857,827 pounds.

Electrolytic Refining of the Precious Metals

The Plant of the Geneva Gold Refinery

BY H. LACROIX*

The electrolytic apparatus used by the Geneva Gold Refinery (Usine Genevoise de Degrossissage d'Or) for refining the precious metals has been described in detail in a previous article (see March, 1909, page 109-111 of this journal). The principle on which it works is well known and we will only give a description of the installation as it has been in operation during the last five years, together with the results which can be achieved.

At the Geneva refinery there are three different processes of electrolytic refining in use, namely, those of Dietzel, Moebius, and Wohlwill. The use of each de-

per thousand at the most. In spite of this all these materials are treated electrolytically without any preliminary chemical solution.

Refining Silver-Copper Alloys

This installation (Fig. 1) consists of ten stoneware electrolytic tanks (Fig. 2) with four diaphragms each. The contents of the alloys treated here vary from 0 to 250 per thousand for gold and from 100 to 700 per thousand for silver.

The Dietzel process in use is well known. The desilverized solution coming from the desilverizing tanks is passed into an upper reservoir, where it is acidified, and is then distributed into the ten electrolytic tanks. The liquor is circulated in these tanks, passing from the cathodes, which are of copper, to the anodes (Fig. 3);

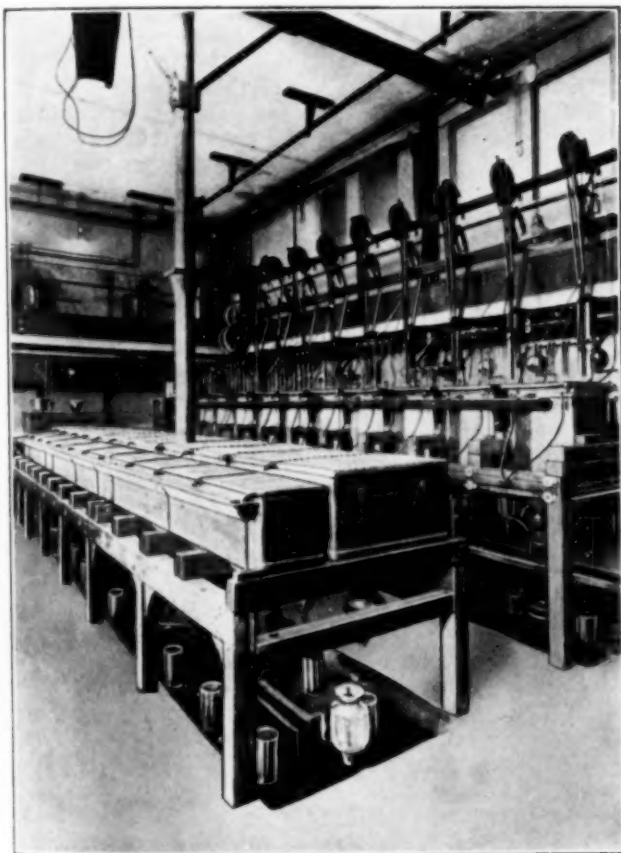


FIG. 1—INSTALLATION AT GENEVA REFINERY

depends on whether the alloy is rich in copper, in silver or in gold. These three different processes have led to the construction of three different types of apparatus, the design of which is based on the same principle but which vary in their dimensions in the materials of which they are made and in their shapes.

Before describing these installations it will be of interest to say that few refineries labor under such unfavorable conditions as the Geneva refinery as regards the quality and the tenor of the alloys to be refined. With the exception of the refining of gold ingots from the mines, all the alloys refined in the gold refinery are derived from commercial bars, which are the residues of all kinds of work shops, poor in precious metal and containing large amounts of base metals, lead, copper, zinc, tin, nickel, aluminium, etc. In the Dietzel refinery the average content of gold plus silver scarcely exceeds 5 to 600 per thousand, and in the Moebius plant the average content of gold plus silver reaches 900 to 910

*Translated by Alex F. Fuerst.

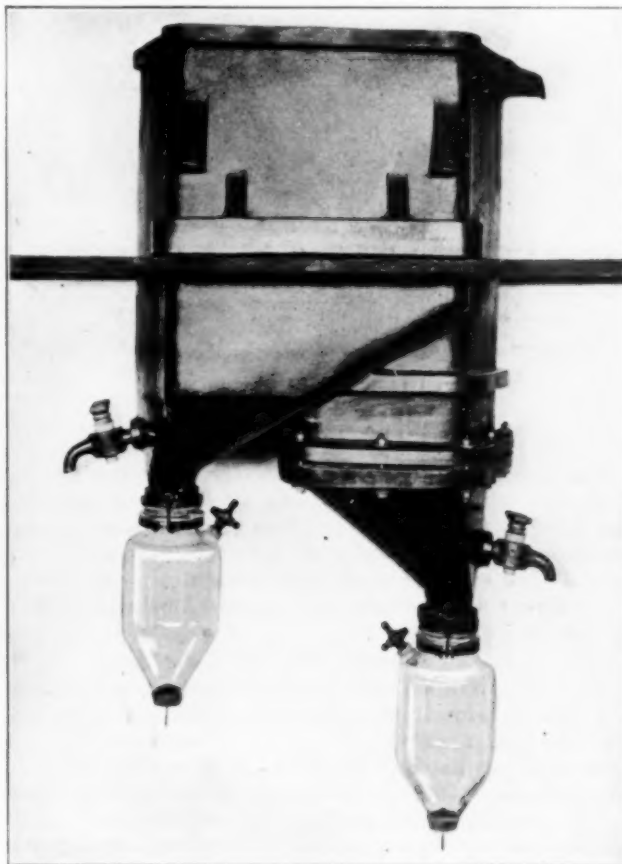


FIG. 2—ELECTROLYTIC TANKS

these latter are suspended inside of diaphragms in which the silver collects. The liquor overflowing from the ten tanks is led through a common drain into a filter press and from there into a collecting tank. From there, by suitable tubing, it is distributed in the desilverizing tanks which are supplied with copper plates. These tanks are arranged in pairs one above the other; each pair is fed separately. After desilverizing, the liquor is collected in a common tank below, from whence an electric centrifugal pump raises it into the upper tank.

As electrolysis proceeds, the gold and insoluble anode residues precipitate and collect in the flask at the right-hand side, while part of the copper deposit which on account of the great density of the current does not adhere to the cathodes drops and collects in the flask at the left. These two precipitates are withdrawn by means of the arrangement described in the above-mentioned article; the arrangement consists of special flasks with globe valves which allow the removal of a stopper in

the lower part. This operation is performed once a day with the flask containing the anodic residues; it requires only a few minutes to do this and no interruption of the circulation in the bath or the passage of the electric current is required.

The anodic gold can thus be withdrawn as fast as it falls and it is not necessary to wait for the complete consumption of the anode.

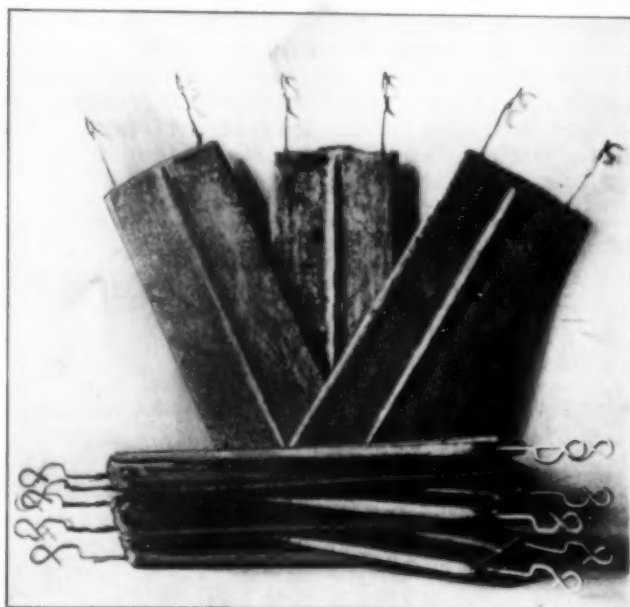


FIG. 3—ANODES

The silver which falls in the desilvering tanks, having a conical bottom, is withdrawn in the same fashion, twice in twenty-four hours. The silver is washed in a revolving drum and the wash water returns automatically to the tanks that fill the flasks after withdrawal. The current density employed is about two amperes per square decimeter.

Refining the Silver

The type of apparatus used for this process differs from the previously described apparatus only in having the left glass flask (of the cathode side) replaced by a stoneware recipient of large capacity. The same is large enough to hold a twelve-hour production of silver and is connected with the tank by a large joint. The anodes are suspended inside of diaphragms and the withdrawal of the anodic residues is accomplished as described above.

The cathodes are of silver or aluminium, outside of diaphragms. The silver deposit is detached by scrapers which automatically scrape from above downwards; the silver falls into the stoneware recipient below, from where it is removed twice a day.

The principle on which this removal is accomplished is the same as above, though modified on account of the withdrawal of a large quantity in one operation. The flask with globe valve is replaced by a funnel provided with a globe valve. The funnel possesses an arrangement by means of which the stopper of the stoneware recipient may be drawn and its contents emptied through the funnel into a stoneware jar below, which is mounted on wheels. By means of this apparatus large quantities of material are withdrawn in a short time and its adoption in other branches of chemical industry should prove advantageous.

As in the previous plant, the bath also circulates from the cathodes to the anodes and is raised outside of the electrolytic tanks automatically from a lower collecting tank to a higher distributing tank.

Refining the Gold

The electrolytic tank of the Geneva refinery has given excellent results in the two processes described above. But in its application to the Wohlwill process of refining gold it has been most successful, rendering this process efficient, rapid, producing a gold of great fineness and reducing manual labor.

The apparatus in use are in principle the same as described above for silver and copper; they are only smaller, have only two diaphragms, and are made of porcelain and the lower flasks are of glass. The anodes are suspended in pairs in each diaphragm from the bus-bars by means of silver hooks. The cathodes are clamped on top in groups of three on three busbars outside the diaphragms.

The chloride of gold bath (*loc. cit.*) circulates from the cathodes to the anodes, rising on the former and descending on the latter, after having passed through openings left in the upper part of the diaphragms.

The circulation takes place in the same direction as would naturally result from the change in concentration at cathodes and anodes of a bath that is left undisturbed. For high current densities such a natural circulation is much too slow, because a rapid impoverishment of the bath near the cathodes would take place and a bad deposit would result. In practice an internal circulation is established by means of a screw propeller.

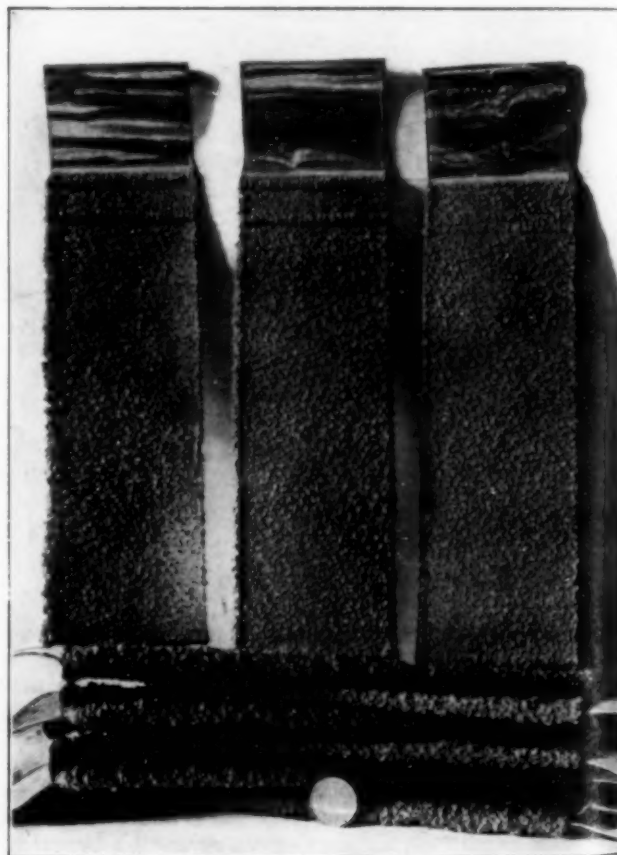


FIG. 4—CATHODES

This manner of circulating the bath in tanks without diaphragms has the drawback of stirring up the precipitate of chloride of silver so that small particles of it are carried mechanically to the cathode gold and lower its fineness. In some refineries such cathodes are once more refined by being used as anodes in other tanks.

By the use of diaphragms, however, in which the level of the bath is a few millimeters lower than on the

outside, the chance of carrying chloride of silver towards the cathodes is absolutely excluded, no matter how rapid the circulation may be. The rapidity of circulation can, therefore, be greatly increased, especially with impure baths.

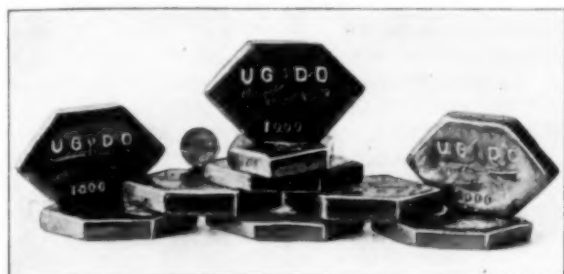


FIG. 5—MELTED CATHODE GOLD

As seen in Fig. 4 the deposit on the cathodes is absolutely uniform all over. In descending along the anodes the circulating bath becomes richer in gold, the particles of chloride of silver are detached and are carried along to the lower parts of the apparatus and collect in the lower flask by gravity. In the apparatus of the Geneva refinery the rate of circulation is about 5 to 10 liters per minute per square meter of cathode for an average bath. This represents a complete renewal of the cathodic solution within five to ten minutes.

The melted cathode gold (Fig. 5) always assays 1000 fine.

The gold bath on leaving the electrolytic tank runs into a lower tank from where it is automatically pumped by electric power into a higher distributing tank. From this latter it re-enters the apparatus after having passed a special steam-heating device where it acquires the necessary temperature. During this circulation outside the electrolytic tank the necessary additions of chloride of gold and of acid are made and a tank holding the wash waters, automatically keeps up the normal volume of solution and compensates for the loss by evaporation. The chloride of silver is removed once a day from the lower flask in the manner described above.

The current density can be pushed to 12 to 14 amp per square decimeter of anode, depending on the copper contents of the solution. The normal density is 9 amp per square decimeter at the cathodes and 11 amp per square decimeter at the anodes. This permits the refining of anodes of 8½ mm thickness in about thirty hours. The fineness in gold of the anodes is about 850 to 950.

For lower fineness a special arrangement is required for the removal of the chloride of silver: either pulsation current may be used, Wohlwill's patent,¹ or scraping of the anodes. The automatic scraper of the Geneva refinery possesses horizontal scrapers moving vertically in front of the anodes and pressing against them on descending, but receding on the rise. The anodes are thus scraped no matter what their thickness or their condition may be.

The diaphragms are sealed inside the electrolytic tanks with the exception of the openings in their upper parts, which establish communication between the anode and cathode baths. Good diaphragms resist well the action of the bath, in spite of its strong acidity and its temperature. Those actually in use have been working now for four years without any repairing.

Before concluding we wish to compare the cost, for example, with those given for the electrolytic operation at the San Francisco Mint, as described² in detail in

the *Engineering and Mining Journal* of Nov. 4, 1911.

This latter installation consists of two series of fourteen rectangular tanks; the cathodes formed in the first series assay, for the reasons given above, 998.7 and are put in again as anodes in the second series, assaying finally 999.7 gold. According to the dimensions given the anodes weigh about 3.35 kg or, for a series of fourteen tanks with eight anodes each, 380 kg, which are worth about \$240,000, or \$480,000 for both series. The interest on this locked-up capital amounts to \$19,200 at 4 per cent per annum.

With the electrolytic tanks of the Geneva Refinery, which yield directly gold 1000 fine and which work with an anodic current density of about 10 amp per square decimeter (as compared with 7.5 amp at San Francisco) the locked-up capital would not be more than \$480,000 $\times \frac{1}{2} \times 7.5/10 = \$180,000$, representing an interest of \$7,200 per year. The saving would therefore be \$12,000 per year without taking into account the interest for the baths and the manual labor.

Geneva, Switzerland.

Superheated Steam on Railway Locomotives

The Midland Railway Company has been making an extensive series of tests with various types of locomotives with the object of ascertaining the efficiency of super-heated steam as compared with saturated steam under the same conditions; and in a paper recently read before the Institution of Civil Engineers Mr. Henry Fowler gave some very interesting statistics which seem to establish the great superiority of the superheated steam; but the author also stated that the Midland Railway Co. had not yet had sufficient experience to be able to give definite figures for costs of maintenance, although everything indicated that they would not be greater than those for engines using saturated steam. Yet he was able to say positively that the wear on the boilers of superheater engines was considerably less than was usually found in locomotives using saturated steam doing similar work; and consequently they could be run for longer periods without being "shopped" and were also a proportionately shorter time out of service. The cost of maintenance was undoubtedly increased by the extra equipment on the superheater locomotive, but he estimated that the saving on boiler repairs would more than compensate for that increase.

The saving effected by superheating, in a series of tests with two similar 4—4—0 engines, each of which had six double runs between London and Leeds, was 23 per cent of coal and 22 per cent of water per ton-mile; and after the superheater engine had run 62,000 miles without "shopping" the consumption of coal and water increased by only 1.5 and 2.8 per cent respectively. Tests with the same superheater-fitted engine against a three-cylinder compound engine showed a saving of 15 per cent of coal and 17.5 per cent of water in favor of the former. Other tests on runs between London and Derby with two engines rebuilt alike in every respect, save that one was equipped with a superheater while the other used saturated steam, gave a reduction of 30 per cent of coal and 34 per cent of water for the superheater. Subsequently in one of the three cylinder compound engines the steam going to the high-pressure cylinder was superheated and a test against an exactly similar engine using saturated steam showed reductions of 25.9 per cent in coal consumption and 22.3 per cent in water in favor of the superheater. No disadvantages were found to result from the high temperature in the hp. cylinder after three months' running.

¹ See MET. & CHEM. ENG'ING, vol. VIII, p. 82.

² See also *Electrochem. & Metall. Ind.*, vol. VI, pp. 355 and 408 (1908).

The Electric Iron Smelting at Hardanger in Norway

BY JOH. HÄRDÉN

The third and last part of Mr. Oedquist's paper on the above subject has now been published¹ and the following is a review of its content.

The paper concludes: The results at Hardanger have shown that coke *can* be used as a reducing agent in furnaces of this type. But this does not of course permit the conclusion that this particular design of furnace is fully suitable for working with coke as a reducer.

The advantage of using coke instead of charcoal in ordinary blast-furnace practice is partly the lower price of the coke, and also the fact that furnaces for coke firing may be built for very large capacities.

In electric furnaces of the type used at Hardanger, however, the coke does not play such a great rôle as regards the quantity of production; in these furnaces the capacity is depending upon the number and the size of electrodes used, which in turn determine the amount of power applicable to the furnace. Consequently the advantage of larger units when coke is used can be disregarded, and only the lower cost of the coke need to be considered.

Against this stands the fact, as well known, that the use of coke has other disadvantages; for instance, that the coke carries various impurities, especially sulphur. These disadvantages are even more pronounced in the case of electric smelting, where the aim has been, at least up to the present, a quality considerably higher than that of an ordinary coke-blast furnace.

Should, therefore, any gain be obtained by using coke instead of charcoal, it must be possible to produce a material cheaper than charcoal-pig, and even so much cheaper that the disadvantages in using coke are fully counterbalanced thereby.

A furnace type suitable for coke as a reducer must, therefore, fulfill the condition that the production of coke-pig from the same kind of ores is at least not higher in cost than if charcoal is used.

The points which are of decisive importance in that case are: Cost of coke, charcoal, limestone and the electric power, as well as the quantities to be produced in each case.

A comparison is made between the conditions at Hardanger, where coke was used, and at Uddeholm and Strömsnäs, where charcoal was employed; the conditions of the comparisons are held to be rather in favor of the Hardanger works. The first one refers to period III at Hardanger and for Strömsnäs for the time from Oct. 1 to Dec. 31, 1912. The second refers to Hardanger period IV and the results from furnace II at Uddeholm from Aug. 4 to Dec. 31, 1912.

The first comparison shows that the ore used in both cases had a high percentage of iron. At Hardanger such ores as Sydvaranger briquets and roasted "red sand" concentrate was used, while at Strömsnäs ores from Kiruna (A), Tuolluvara and Lerberg were used.

The yield of pig iron was: At Hardanger, 69.1 per cent; at Strömsnäs, 65.38 per cent. Consequently the ore used at Hardanger was richer, but as the Hardanger works used coke, a very basic slag was necessary, which lowered the yield of iron calculated in per cent of total material charged to only 56.4 per cent, while the corresponding figure for Strömsnäs was 61.78 per cent, because charcoal was used at the latter place, wherefore less limestone was required.

At Hardanger 336 kg coke and 330 kg limestone was used, while at Strömsnäs 23.58 hectoliters charcoal (the

weight of the charcoal is not stated, but the above figure corresponds to about 65 bushels) and 90 kg limestone, all per ton of pig iron produced.

During the same period the yield of pig iron at Hardanger was 2.01 tons per calculated horse-power year, but as the conditions of the furnace were such that this figure is too low, as only about two-thirds of the available energy could be utilized in the furnace, it is to be assumed that 3.015 tons could have been produced per calculated horse-power year.

The cost of electric power, at a price of 33.33 shillings per horse-power year should in that case be 19.18 shillings per ton instead of 28.76 as stated before. The corresponding cost for Strömsnäs, under the assumption that the same kind of ore was used, giving a yield of 69.1 per cent of pig iron, would be 12.96 shillings instead of 13.69 per ton.

The economic results are clearly shown in Table XI.

TABLE XI

| | HARDANGER, PER III | | | STRÖMSNÄS | | | |
|----------------|--------------------|---------------|-----------|-------------|-------|---------------|-----------|
| | Kg. | Cost, per Ton | Shillings | Hecto-litre | Kg. | Cost, per Ton | Shillings |
| Coke..... | 336 | @ 26/8 | 8.95 | ..... | ..... | ..... | ..... |
| Charcoal..... | ..... | ..... | ..... | 23.58 | ..... | @ 8/8 | 15.70 |
| Limestone..... | 330 | @ 5/6 | 1.83 | ..... | 90 | @ 5/6 | 0.50 |
| El. power..... | ..... | ..... | 19.18 | ..... | ..... | ..... | 12.96 |
| Sum total.... | ..... | ..... | 29.96 | ..... | ..... | ..... | 29.16 |

When the results of Hardanger period IV and the Uddeholm furnace No. II are compared, it is found that the yield of iron from ore was 58.05 per cent at the former and 58.6 per cent at the latter, while the percentage of iron calculated on total amount of charged material was only 41.65 per cent at Hardanger against 52.9 per cent at Uddeholm.

The ore at Hardanger was Persberg and roasted red sand; information as to the ore used at Uddeholm is lacking, but it was presumably Tuolluvara and Persberg.

The coke consumption at Hardanger may be given as about 385 kg per ton of iron (in reality as much as 441 kg was used during the period), but as no gas circulation was used, it is fair to assume that if such had been employed, the consumption would have been about 336 kg, or the same as in the foregoing period.

The consumption of charcoal per ton of pig iron at Uddeholm was 21 hectoliters (about 57.5 bushels) and 186 kg of limestone, while at Hardanger 678 kg limestone per ton of iron was used.

The yield of pig iron per calculated horse-power year during period IV was 1.87 tons. As no gas circulation was used, it may be assumed that this figure could have been increased to 2.2 tons with the gas circulation (see diagram No. 1) and the calculated cost for electric power would have been 28.22 shillings instead of 33.21 shillings.

The corresponding cost at Uddeholm should, if a similar ore had been used, been slightly higher than

TABLE XII

| | HARDANGER, PERIOD IV | | | UDDEHOLM FURNACE NO. | | | |
|----------------|----------------------|---------------|-----------|----------------------|-------|---------------|-----------|
| | Kg. | Cost, per Ton | Shillings | Hecto-litre | Kg. | Cost, per Ton | Shillings |
| Coke..... | 336 | @ 26/8 | 8.95 | ..... | ..... | ..... | ..... |
| Charcoal..... | ..... | ..... | ..... | 21 | ..... | @ 8/8 | 13.98 |
| Limestone..... | 678 | @ 5/6 | 3.76 | ..... | 186 | @ 5/6 | 1.03 |
| El. power..... | ..... | ..... | 28.22 | ..... | ..... | ..... | 16.82 |
| Sum total.... | ..... | ..... | 40.93 | ..... | ..... | ..... | 31.83 |

¹ Teknisk Tidskrift K. O. B., Feb., 1914.

stated (in Table X), namely, 16.82 shillings instead of 16.66 shillings. The results are shown in Table XII.

In Tables XI and XII, a comparison of results is made with ores of practically the same percentage of iron, and under conditions which are in favor of the Hardanger works, inasmuch as all disadvantages adherent to the use of coke are not considered, yet the comparison of Tables XI and XII shows that for these cases and the prices given the smelting with coke was more expensive than with charcoal.

If all factors, such as they appear in reality, are fully considered, we find that the cost per ton of pig iron in the first case is 9.62 shillings higher and in the second 14.23 shillings higher at Hardanger than in corresponding cases at Strömsnäs and Uddeholm.

If the electrode consumption is considered (although it is stated that only 14 kg was consumed per ton of iron during period IV) we find that the costs at Hardanger are respectively 12.42 shillings and 16.56 shillings higher per ton than at Strömsnäs and Uddeholm. Should all disadvantages experienced when coke was used as stated above be considered the figures for the results at Hardanger would be even more striking; in addition to this comes the question of quality of the material produced, a matter which has not been touched at all so far.

According to Mr. Oedqvist's opinion, these unsatisfactory results when coke is used must, on the strength of the above, be due to the type of furnace used, at least in the main points.

That better results could have been obtained at Hardanger, if certain alterations had been carried out, is beyond doubt, but judging from the results arrived at in the Hardanger Works, it is evident "*that the furnace such as it was and was operated at Hardanger must be regarded as not suitable for use of coke as reducing agent.*" (Italics by Mr. Oedqvist.)

Regarding the actual reasons why this furnace type should not work satisfactorily when coke is used as reducer, the author of the paper states that not only is the charge very much more compact and presents greater difficulties for the gases to penetrate, also preventing a good and intimate contact between the ore particles and the reducing agent, but still more important is the fact that the great variations in the electric resistance caused by the setting of the charge in the smelting zone, are very detrimental.

These variations extend naturally to the whole system and influence the power supply in such a way that the average load on the furnace for a given amount of available power is considerably reduced, when coke instead of charcoal is used. A direct consequence of this is that the total production and efficiency of the plant is reduced.

When coke is employed instead of charcoal, a much larger per cent of limestone in the charge, on account of the higher sulphur content, is also required. This, of course, causes a direct increase in cost. Furthermore, the charge is diluted with ballast, so that the percentage of iron in the charge is less, which increases the amount of power required for smelting, or in other words, the production is reduced.

Against this stands the fact that the coke is so much less expensive than charcoal, the question is if these two factors counterbalance each other or not.

It would have been of great interest if the author had been able to give the respective costs on the spot of both coke and charcoal, per quantity required in either case. This would have elucidated the case considerably.

What has been said here refers more or less to all furnaces in which electrodes are used and coke employed as reducing agent.

It also shows clearly that the causes for the unsatisfactory results of the smelting at Hardanger were both many and important, and one must not thereby lose sight of the difficulties and drawbacks caused by the type of furnace employed.

On the contrary, the heavily paid-for experience gained at Hardanger should serve to assist in a more satisfactory solution of this great and important question.

That this type of furnace has rendered good results when smelting with charcoal, but proved a failure when coke was used, should on no account be considered as decisive in the question of using coke for iron smelting in general. We must on the contrary fully realize that if electric iron smelting shall occupy the place in the metallurgy of iron, which it is fully justified to attain, it will be necessary to adopt a cheaper reducing agent than charcoal, such as coke or stone coal.

Our endeavors must therefore be to aim at a furnace type which will permit of the use of an inexpensive reducing agent and yet produce a good and even quality, at a price which will stand the strongest competition.²

This concludes Mr. Oedqvist's paper. The causes of the unsatisfactory working at this plant should be clear on the main points if the statements made in Mr. Oedqvist's paper represent all the determining factors. This, of course, it is exceedingly difficult to ascertain, as there are bound to be a number of points, which, taken one by one, appear insignificant enough, but in united effect may turn the balance one way or the other. One cannot be too careful in attributing the failure of a plant of this kind to any one specific cause, since there are so many details, which all require a special study.

It is almost unthinkable that such a large plant, involving so many interests, should have been built without preceding trials on a fair scale under conditions as nearly identical as possible. Several furnaces of this type, as is well known, have been working successfully with charcoal, and if the new plant was to work on coke, it seems that the previous working for a few months on coke with the ores in question in one of these already erected plants would have been money well spent, even if it had been necessary to somewhat alter the prevailing arrangements at these furnaces.

Again, if such trials have been carried out, although not mentioned in Mr. Oedqvist's paper, the results obtained, if published, would be of great value as a comparison, and might help to clear up the matter.

It may be argued that the older furnaces mentioned belong to different concerns, who had no interest in the welfare of a new rival plant. But even so, the possibilities of using coke instead of charcoal should have been a strong inducement to carry out such tests, since, as already stated, the charcoal is becoming more and more scarce every year.

As regards some of the difficulties in using coke when smelting electrically in a shaft furnace, the present writer has had opportunity to encounter a few. When carrying out preliminary tests for the Electric Tin Smelting in Cornwall, related in METALLURGICAL AND CHEMICAL ENGINEERING, September, 1911, and elsewhere, a modified kind of shaft furnace was also tried. For certain reasons, coke of various grades was tried in this as a reducing agent. But it was soon found that the results obtained did not encourage a further use of coke under the same conditions. The average working voltage went down as low as 32 to 35 volts, with a corresponding increase of the current, which caused

² Correction in the translation in Teknisk Tidskrift: In Table IV the figure 44.6 should read 41.65. The electrode-diameter given as 500 mm, should read 600 mm in all three plants.

overheating both of transformer, electrodes and other parts. If the voltage was increased forcible arcing took place followed by a volatilization of metal and general disturbance of the running.

Also, although the total input of power was held at about the same figure as before, the production went down considerably. It was found almost impossible to obtain a satisfactory slag; it was either too viscous or contained a too high percentage of metal.

Instead of "doctoring," however, with the furnace, the use of coke was simply abandoned after a few smelts, since other more suitable reducing agents could be obtained at almost the same price; even had this not been the case, the increased costs when using coke would have justified a more expensive reducing agent.

It shall not be said that coke *could* not be used for the purpose; with correspondingly larger electrodes and allowing for a higher power consumption it is quite feasible that coke could have been successfully used. But the type of furnace *alone* was not the chief fault; in fact, the writer believes that with suitable conditions generally and a different method of working, the same furnace with somewhat larger electrodes would have worked very well with coke, if tolerably free from sulphur. The conditions, however, were such that the use of a more suitable reducing agent became more economic.

Variations in voltage, as stated by Mr. Oedquist, were noted in this instance as well, but in no cases to any such extent as mentioned. On no occasion was a higher tension than 65 volts per phase required at the furnace, even when starting up from cold; though the furnace was, of course, very much smaller, which may to a certain extent account for this fact.

The use of coke, in that instance, had one redeeming feature: the electrode consumption was somewhat smaller, probably because the well conducting coke piled up round the carbons and acted partly as secondary electrodes. But the difference was very slight, and had no appreciable influence upon the economic result, since the heavier slag sometimes formed crusts on the electrode stumps, which made it difficult to use up the butt ends.

One of the chief drawbacks, however, was the low resistance of the coke, which caused the increase in current and a decrease in voltage, also altering the zone of reaction.

Reverting to the iron smelting, Dr. Lyon says: "I have already mentioned the relative value of coke and charcoal as a reducing agent in the electric furnace, that we need more information along this line, and that we expect to get it. It is to be remembered that it has been only two or three months since the plant at Hardanger in Norway shut down because they could not use coke as a reducing agent. In California they have found out the same thing; that is, they cannot use coke alone, due to the high conductivity of the same.

"It is also to be remembered that the iron furnace is a resistance furnace, that the heat is created by the resistance which the charge offers to the current, and that as coke is a better conductor than charcoal, less resistance is offered by the charge when coke is used as a reducing agent, and hence the current consumption per ton of metal produced is greatly increased. However, as before stated, we still need more information on this subject and hope very soon, as a result of some experimental work which we are contemplating, to secure the same."

These remarks corroborate the observations made above, and it will be interesting to see to what result further researches will lead. Some metallurgists sug-

gest to abandon the use of a shaft-furnace altogether; although this would simplify the work in the smelting zone and lead to a simpler design generally in one way, it is difficult to say if the sacrifice of the pre-heating of the charge in the shaft is justified on this account.

Other remedies may be and will be found; so much work and capital has already been spent on this problem that it seems likely that it will be satisfactorily solved in a not too distant future.

The First Chandler Foundation Lecture

One of the most interesting features of the celebration of the fiftieth anniversary of the Columbia School of Mines on May 29 was the inauguration of the Chandler Foundation lectureship founded in honor of the only surviving founder of the School of Mines, Dr. Charles F. Chandler. The first Chandler Foundation lecturer was Dr. Leo H. Baekeland.

To both a grand reception was given when they appeared in the large and well-filled lecture hall of the Havemeyer Building. Dr. Chandler spoke charmingly of olden times and touchingly of his former colleagues, especially of Eggleston, and then introduced the lecturer of the day, Dr. Baekeland. The title of Dr. Baekeland's lecture was "Some Economic Aspects of Industrial Chemistry."

As Dr. Baekeland's brilliant address dealt in crisp, epigrammatic form with almost anything within the sphere of industrial chemistry, it is plainly impossible to do it justice in abstract. All we can do here is to sketch briefly the leading ideas of the lecture. Publication of the lecture in full is reserved for a later issue.

Dr. Baekeland emphasized the interrelation between chemistry and civilization and showed how industrial chemistry had developed in different directions and at different times in France, England, and Germany. A large part of the lecture dealt with the fixation of atmospheric nitrogen—"an epos of applied science," the economic problem and its different technical solutions—production of nitrate, cyanamide, nitrides.

Many chemists regard a process too much from the narrow viewpoint of the chemical reactions involved and overlook all other considerations. But such "secondary" considerations are often of decisive importance for the commercial success; for instance, the cost of transportation.

This was shown in great detail by Dr. Baekeland by the example of the Leblanc soda process. A very well-worked out process, known in all details, brought to perfection, it is now in languishing agony succumbing to "secondary" considerations. The chlorine industry, its present status and probable future were discussed.

The importance of cheap power in the electrochemical industries was pointed out, but it was also pointed out that cheap power is not everything. The cost of water-power is high in the United States as compared with Norway; further, while the Norwegian water-powers are close to the ocean, the American water-powers are not. The possibilities of gas power were discussed. Dr. Baekeland then turned to agriculture which is "but a branch of industrial chemistry," and to the possibilities of photochemistry.

The completion of the Panama Canal shows what a government by engineers can do, as against a government by politicians. We have still too many men of yesterday. What is needed are men working not for to-day, but for to-morrow.

After the close of Dr. Baekeland's brilliant lecture President Butler presented in a felicitous little speech ("that the punishment may fit the crime") the first imprint of the Chandler gold medal to Dr. Baekeland.

²Transact. Am. El. Chem. Soc.: XXIV, p. 151.

Chemical and Industrial Applications of Mechanical Refrigeration

By H. J. Macintire

In the foregoing articles an attempt has been made to describe only the cycle of the refrigerating medium. Before proceeding to the direct application of mechanical cooling to industries it is wise to consider certain general details, such as the use of a brine (or cold air), of direct expansion, the operating back pressure, etc.

Generally speaking it is more advantageous to use direct expansion. By this is meant that the liquid refrigerant is permitted to pass directly to the cooling system, where it vaporizes and returns to the refrigerating machine. As the condenser pressure is usually about 150 lb. gauge, the liquid refrigerant is carried to the expansion valves in the refrigerating coils automatically (hydrostatically). The conveying pipe can be relatively small and need not be insulated unless the pipe has to be carried through warm pipe shafts or rooms. The return pipe, however, has to be insulated and has to be relatively large. Pressure drop in the suction return line (the difference between the cooling pressure and the back pressure on the compressor) usually must be kept below 5 lb. and this varies directly as the length of the return line, and inversely as a function of its diameter. There are also possibilities of serious breaks in the pipe line, which may be injurious to the goods being cooled, or to personal safety.

With direct expansion it must be remembered that the refrigerating machine must operate when cooling is desired. With a brine or cold air a cooler is placed in some convenient place (usually the engine room itself) and the brine or air is circulated over the cooler and into the rooms to be cooled. This circulation is a forced one, requiring (except in special cases) the continual use of power for this purpose.

Thermodynamically, there is a loss of efficiency in the method, especially where brine is used, on account of the second system of cooling coils. Usually there is required from 4 to 5 gal. of brine per minute or about 500 cubic feet air per minute per ton of refrigeration.

With brine there is a very decided advantage in not having to use the refrigerating machine all the time, refrigeration being obtained by the circulation of cold brine, previously cooled.

In certain industries, where "peak" loads occur a smaller (and therefore cheaper) refrigerating machine may be installed in conjunction with a large brine storage tank—brine being cooled by continuous operation of the refrigerating machine—the temperature of the brine being lowered during the periods of small demand for cooling and raised when the demand on the system is greater than the normal capacity of the machine.

The operating back pressure used on the compressor must not be too low. A consideration of part 1 of this series will show that the operating back pressure determines the temperature at which refrigeration takes place. A decrease of back pressure decreases this refrigerating temperature and the refrigerating capacity of the machine, but increases greatly the displacement of the compressor per ton of refrigeration and the power required from the prime mover. A regulation of the back pressure to suit the refrigerating temperature is therefore desirable.

Cooling of Liquids

One of the principal uses of refrigeration is in the cooling of liquids, such as water for drinking pur-

poses or for steel tempering, beer wort, oil, milk, brine, etc. These are usually the simplest of all refrigerating problems, as the refrigerating "duty," in tons of refrigeration, is obtained by the product of the pounds of liquid cooled per minute, times the specific heat, times the number of degrees cooled in degrees Fahrenheit, divided by 200.

The specific heat is frequently a variable, as in brine, beer and oil refining. The latter case as well as the abstraction of naphtholene from varnish oil, has another detail which must be considered; namely, the congealing and freezing of a solid which is later separated from the oil by means of a filter press—paraffine in the case of mineral oil—and accurate calculations should allow for the latent heat of fusion of this content.

Cooling of Air

Frequently, in the process of cooling of the fluid, whether it is in the soap manufacture, or the separation of gasoline from natural gas, there is another factor entering into the computation; namely, the latent heat of condensation or of fusion. This is particularly true in the cooling of air—one of the most common applications of mechanical refrigeration to chemical industries—such as the dry blast for blast furnaces, the manufacture of gelatin films, chocolate, etc.

It must be remembered that atmospheric air contains water vapor—an amount depending on the temperature and humidity of the air. As a rule, a lowering of the air temperatures of 10 to 15 deg. will bring the air to this condition of saturation and still further decrease in temperature will mean the precipitation of moisture, requiring nearly 1000 B.t.u. of refrigeration per pound of water condensed.

Frequently, the air is cooled below 32 deg. Fahrenheit (especially that air near the cooling pipes) and the condensed water vapor is also frozen on the cooling pipes; the frost increasing in thickness until the pipes became practically useless for further cooling until they may be defrosted.

The arrangement allowing frost to freeze to the pipes is obsolete for large installations running continuously, for several reasons. First, there is required considerably more refrigeration in order to freeze the condensed moisture, and second, there is considerable variation of duty obtained from the pipes as well as trouble and expense in defrosting.

A better value for the coefficient of heat transmission and an elimination of the frost is obtained by wetting the cooling coils continuously with some convenient liquid—such as brine. The brine is allowed to fall from one horizontal pipe to another, and finally to a cold basin where a pump raises it up to the top of the coils again. The brine keeps the pipes continually wetted, and absorbs the condensed water vapor—the latter diluting the brine by a like amount.

The brine must be strengthened by means of a concentration apparatus like that used in the so-called dry-blast process of the Carnegie Steel Company, or by the addition of more salt.

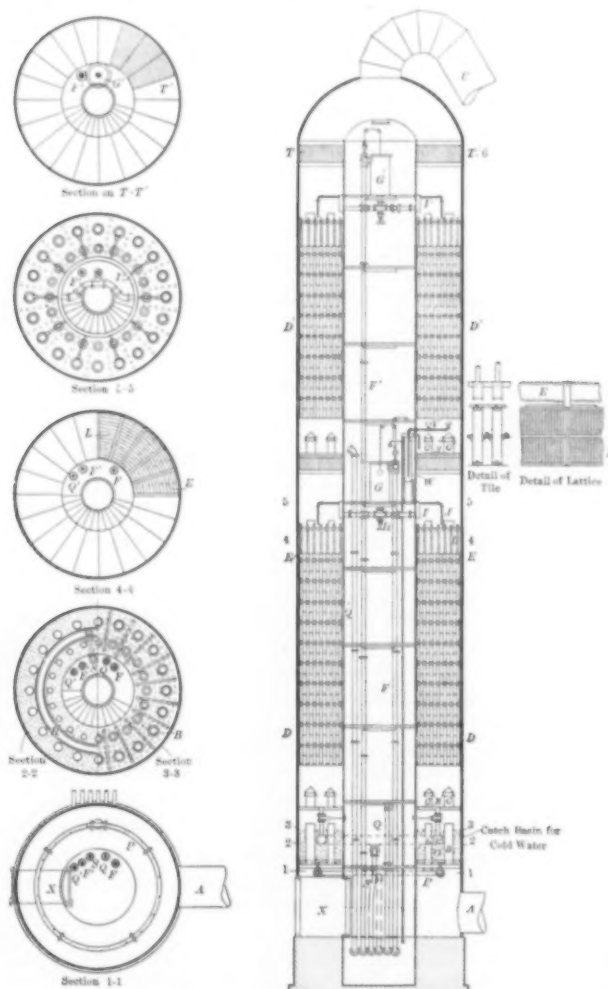
The illustration shows the former—designed for the cooling of 40,000 cubic feet of free air per minute to 25 deg. Fahrenheit in two stages. In the first stage the air enters under atmospheric conditions and at the base of the tower and is cooled to 39 deg. Fahrenheit, in contact with *water-wetted* pipes. The air leaves this stage at 39 deg. Fahrenheit and contains 35 grains of moisture per pound. In the second stage the air comes in contact with the *brine-wetted* pipes in the upper part of the tower and leaves the tower finally at 25 deg. Fahrenheit and with 19½ grains of moisture per pound of dry air.

A calculation for such a tower for, say, a typical summer day in Pittsburgh, would be for air at 90 deg. Fahrenheit and 86 per cent humidity using a psychrometer chart for the calculations:

- (1) To cool 1 lb. air from 90 to 84.8 (dew point) 1.33 B.t.u.
- (2) 84.8 deg. to 25 deg. F. and condense moisture 39.8
- (3) To cool condensed water for an average temperature of 26.4 deg. F.... 00.7

41.83

The specific volume of air at 90 deg. and 85 per cent moisture is 14.47 cubic feet.



COOLING OF AIR IN TWO STAGES

Total number of pound air cooled per minute is 40000

— = 2764.

14.47

Total refrigeration = $2764 \times 41.83 = 578$ tons re-

200

frigeration.

It may be added that the dry blast requires considerably less power in the blowing engine than does the common system (as well as a smaller piston displacement) and that the uniformly low water content in the air gives a much cheaper pig iron as well as of better quality of production.

Shaft Sinking

As a final application of refrigeration may be given

that of shaft sinking, excavation or foundation work in ground of boggy or partially fluid condition. Here it is necessary to freeze the vicinity of the work to be performed in order to obtain a zone of sufficient strength to withstand the inward pressure as soon as excavation is commenced.

In shaft sinking of much depth the main difficulty is to drill the holes—within which the brine pipes are placed—sufficiently parallel to each other. Should the drilled holes be out of plum the resisting wall of frozen material may give way. The brine tubes are frequently 4 in. in diameter and are placed about 3 ft. apart. The depth of practical excavation is usually 400 to 500 ft., but depths of 1300 ft. have been attained. As a rule $MgCl_2$ brine only is used on account of its stability in solution as well as on account of its ability to carry low temperature (— 15 deg. F. to — 20 deg. F.) without freezing. The time of freezing varies from 3 to 12 months, depending on the size of and condition of the work.

A knowledge of the composition of the material to be frozen must be had if accurate calculations of the refrigeration duty are to be made. The specific heat of dry minerals is nearly 0.2 and the density about 1.8, whereas the water content may vary over a large range. It is usual to figure on a frozen section of 3 ft. on the inside and 1½ ft. on the outside of the circle of brine pipes and a cooled section of about 5 ft. thickness on each side of the frozen area. The calculation of the necessary refrigeration requires a consideration of the cooling of the solids, cooling of the liquid content to 32 deg. F., freezing of this water and finally the cooling of the ice formed. A good rule is to allow an average of 85 B.t.u. per hour of refrigeration duty per square foot of brine pipe cooling surface and to allow about 33 per cent for losses.

University of Washington, Seattle, Wash.

Copper in Scotland

The high reputation of the British Geological Survey for completeness and accuracy has been impeached through the accidental finding by a boy, innocent of geology, of a piece of copper-bearing ore on the Otter estate in Argyllshire. It appears that the youth found the lump of ore more than eight years ago, and kept it until some two years ago, when he showed it to a mining expert in Glasgow, whose investigations have resulted in the discovery of three fairly good lodes at Kilfinan, Inveryne and Tighenraed.

The Kilfinan lode was found in exploring a barren field which no amount of manuring would induce to grow even a crop of grass and which local tradition described as being under a curse. It is the best of the three finds and is being worked by the Otter Copper Company, Ltd. Shortly after work was begun a vertical vein of copper carbonate, some 2 in. thick, was found; and about 40 ft. further on this vein opened out to a compact mass of gray sulphide from 1 ft. to 2 ft. thick.

The authorities of the Geological Survey have naturally evinced great interest in the proceedings, and have deposited some rich specimens of ore in the Geological Museum at Jermyn Street. Until the discovery was made it was assumed that metalliferous ores did not exist on the eastern side of Loch Fine to the same extent as on the western side; and the geological map shows no copper in that district. So far the mining operations have resulted in 266 tons of the best ore being smelted with an average yield of 15 per cent, together with about 70 tons of dump which gave 3½ per cent. The mines are in the immediate vicinity of tidal waters and there is every facility for economical working and transport.

Notes on Unit Cost-Keeping in Metallurgical Work

BY JUSTIN H. HAYNES

In the last few years scientific management has become a live issue in all lines of industrial work. Many attempts have been made to adapt the new ideas and systems to mining and metallurgy, but with very little success up to date. Usually the number of clerks required to execute the efficiency idea is prohibitive. The route clerk, the motionstudy clerk, the various supply clerks, etc., almost lead a manager to believe that more men are necessary in the office than in the works.

In all so-called efficiency systems, or schemes for scientific management, great stress is laid upon the necessity of some plan of payment by means of bonuses, but very little information is given as to how this should be done. Time-studies are dwelt on at great length but do not seem to give the desired result. Time-studies are spasmodic and unreliable: spasmodic, because they are made only when the idea so strikes the executive in charge; unreliable, because they usually are made for very short periods of time, giving results which are sure to be either above or below the average. The only time-study that is absolutely reliable of work being performed, is the average of the work accomplished over a long period of time such as a month or a year. Time-study should come later, and will show the small leaks in detail.

Cost-Keeping Versus Bookkeeping

The whole object of the efficiency movement is a greater production for a less sum of money. This makes cost-keeping one of the most essential points of the system. The mistake usually is made of allowing the bookkeeper or accountant to devise the cost system. Bookkeeping is a function of accounting. Cost-keeping is a function of engineering. The objects of the two are entirely dissimilar; they are looked at from entirely different points of view, and it is next to impossible to combine them. The bookkeeper and accountant must show information of value to the manager, directors and stockholders. He must show the debits and credits, resources and liabilities; he must show the difference between total cost and total income; in other words, he must show whether the property is making a profit or is losing money. In this way he is able to guide the directors as to how much money they can spend on betterments, what dividends can be declared, and similar questions. Cost-keeping is for the engineer or executive and shows in detail the cost of each department and what has been accomplished for the money spent. It is without value unless it aids him in controlling the working details of the property.

Accountants say that cost-accounts must be tied to the total actual expenditure in order to be of any value. Engineers say that cost-accounts must be tied to the work accomplished in order to be of any value. The latter view must necessarily be correct; but preferably, the cost-account should check both ways. Cost-keeping is not an exact science, for large errors creep in at the very basis of the data. A man working eight hours will have his time distributed over, say, five or six departments, and it is impossible to obtain the exact time he spent in each department. This reason alone must make cost-keeping merely a very close approximation; and the fact that an item will vary at the end of the month a few dollars more or less from the actual sum paid out by check does not decrease its value to the executive.

What the Engineer Wants to Know

The point the engineer does have to know is how

much was accomplished for each dollar spent, and usually the books do not take accomplishment into consideration in any way. In fact, cost-keeping as handled by the bookkeeping force is an attempt to fulfill the growing desire for detailed cost, but does not furnish the information that an engineer versed in cost-keeping would give. To know the exact cost of a certain piece of work, and to be able to compare it with other costs for the same work, it must be reduced to a unit basis. The meat of the whole subject lies in the unit system of cost-keeping, and in what unit is used.

For example, if a new roof is put on a mill building the accountant is interested primarily in crediting the carpenter with one day's work at so much, and later seeing that it is balanced by the debit of the day's pay given to the carpenter. The engineer does not care primarily about the man receiving his pay, but is interested in knowing how many squares of roofing were put on for \$1. The engineer must know this in order to compare the cost of this roof with the cost of other roofs under similar conditions, and whether the mechanic was working efficiently or not. The stockholder or director, and therefore the accountant, is not interested in how much this roof cost per square, but is interested in knowing the relation of the total improvements or repairs to the total operating expense. Therefore, in a metallurgical mill where the costs are finally converted into cents per ton, this roof will be classed as repairs amounting to so many cents per ton. Your engineer could not tell from the fact that general repairs on this roof amounted to 1½ cents per ton of ore treated, whether the work was efficiently done or not, but if he knew the cents per square for putting on the roof he could then judge of the efficiency of the work. Thus the value of different units becomes very apparent. If a carpenter puts a new stairway in a mill, which cost unit will best serve the engineer — cents per ton of ore treated, or dollars per thousand feet of lumber? It is unfortunate that most of our cost-keeping systems are inaugurated by accountants.

It is a comparatively easy matter to keep track of the amount of work accomplished per day by miners, trammers, etc. It is not so easy to keep track of the work accomplished by men on shift in the mill, such as battery men, cyanide men, crusher men, etc. This is due to the fact that the latter are on duty merely to watch machinery in operation and see that the wheels keep turning. Therefore special methods have to be introduced for such cases. To keep track of all men at work, with the exception of men on shift, requires merely that the records, in addition to showing the number of hours worked and the rate of pay, must show also the amount of work accomplished, based on some unit.

Card System of Unit Cost-Keeping

The cards illustrated herewith show how this can be done in the ordinary routine of office work, without requiring extra clerks. After these records have been kept for a number of months, showing the average cost per unit for each line of work, standards can then be obtained from which bonus systems can be very easily calculated, following any of the standard plans desired.

A very important card is that illustrated by Fig. 1, which shows in detail the amount of work accomplished by each man, with cost of work done, and readily allows the latter to be converted into unit cost for each line of work. As illustrated, the card is very satisfactory, but slight changes in its form may be desirable under special conditions. These cards are usually made 5 in. by 8 in., to fit standard filing systems. Each card represents a period of seven days, and four or five cards are required for each man per month. It will be noted that

the days of the month are arranged in the style of a calendar, with a check mark opposite the week for which the card is used. By this system a card is complete at the end of every seven days; and if the weekly system of reports is used, the week will always end on the 7th, 14th, 21st, 28, and, excepting February, on the 30th or 31st, giving in all cases, except February, one week containing two or three days. The distribution is left blank on the printed card so that in complicated

| Name John Jones Occupation Miscellaneous Date March 1914 | | | | | | | | | | |
|--|---------|---|---|---|---|---|---|---|---------------------------|-----------|
| DISTRIBUTION | UNIT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | TOTAL AMOUNT ACCOMPLISHED | UNIT COST |
| Repairs on Mill | 1000 ft | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1.00 |
| Building | 1000 ft | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1.00 |
| Water Supply | 1000 ft | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1.00 |
| Mill | 1000 ft | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1.00 |
| Gr. Breaking | 1000 ft | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1.00 |
| Gr. 2-7 ft x 10 | 1000 ft | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1.00 |
| Gr. 1-10 ft | 1000 ft | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1.00 |
| Warehouse | 1000 ft | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1.00 |
| Unloading Silos | 1000 ft | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1.00 |
| Gr. punching | 1000 ft | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1.00 |
| Gr. 1-10 ft | 1000 ft | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1.00 |
| TOTALS | | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7.00 |

FIG. 1—CARDS FOR UNIT COST KEEPING

work any distribution can be inscribed, thus extending the system to as fine detail as is necessary.

The specimen card illustrated is filled in to cover different rates of pay, different units of accomplishment, and a wide variety in the lines of work performed. Each distribution is allowed two lines. On one of these lines the time is kept as in a standard time-book, except that the time for any certain day is entered in dollars and cents instead of hours. The second line of the same distribution is used for the amount of work accomplished. In this way no time-book is necessary as the cards form the time-book for one week. If it is desired that one card should report a month's work the same plan can be followed except that a larger card is required. The two lines given on each distribution allow for main-distribution, together with a line for sub-distribution.

This card allows the efficiency of each man to be

| Dorr Thickener 33'x12' Erecting-Labor only | | | | | | | | | | |
|--|-----------------------|------|-----------------------------|---------|----------|------------|---------------|------|------------|-----------|
| Date | Operation | Unit | Am't Ac. | No. Men | Time | LABOR COST | Supplies Used | Cost | TOTAL COST | COST UNIT |
| 10-1 | Complete Thickener | #1 | abde | | | 84.75 | | | 84.75 | |
| 10-2 | erection | #2 | abde | | | 78.65 | | | 78.65 | |
| 10-3 | 18' of Tank and Mch'y | #3 | abde | | | 69.85 | | | 69.85 | |
| Individuals | | Rate | Maximum | 63.85 | Average | | | | | |
| a Green | | 5.00 | Maximum | 84.75 | Standard | | | | | |
| b Bush | | 5.00 | REMARKS: Complete Thickener | | | | | | | |
| c Martin | | 3.25 | above joists. | | | | | | | |
| d Linker | | 3.25 | | | | | | | | |
| e Cottrell | | 3.00 | | | | | | | | |

FIG. 2—CARDS FOR UNIT COST KEEPING

readily calculated; and an average record for several months will give a very clear comparison of his work with that of other men on the job. At the same time it takes practically no more office work to keep a card of this kind, than to keep his time without a unit system of accomplishment. In the case of gang-work in which, say, six carpenters together put up six thousand feet of lumber in one day, it is very difficult to tell the amount each man has accomplished by himself, as his card must necessarily show one-sixth of six

thousand feet, or one thousand feet, erected. This is not detrimental to the system in any way, as his unit cost will then increase or decrease with the unit cost of the gang; and the changes in the gang, which are certain to occur from time to time, will give a line on the man's efficiency, even though his work is greatly complicated with that of other men.

Figures 2, 3 and 4 show another form of card which

| Com Shaft. Drilling for Conda fasteners | | | | | | | | | | |
|---|-----------|-------|---------------------------------|---------|----------|------------|---------------|------|------------|-----------|
| Date | Operation | Unit | Am't Ac. | No. Men | Time | LABOR COST | Supplies Used | Cost | TOTAL COST | COST UNIT |
| 10-1 | Drilling | 1 cam | 6.00 | a b | | 4.70 | | | 4.70 | |
| 10-2 | " | " | 3.00 | a | | 3.95 | | | 3.95 | |
| 10-3 | " | " | 3.00 | a | | 3.40 | | | 3.40 | |
| Individuals | | Rate | Maximum | 3.40 | Average | | | | | |
| a Goglin | | 3.00 | Maximum | 4.70 | Standard | | | | | |
| b Martin | | 3.25 | REMARKS: 6" Shaft Hand Drilling | | | | | | | |

FIG. 3—CARDS FOR UNIT COST KEEPING

is very convenient, as it can be adapted to practically any type of work. As illustrated they are used entirely for checks on the cost of special work, and do not give the exact figure of efficiency for any one man. Nevertheless they are very valuable to the engineer or superintendent as a check on his costs. Fig. 2 refers to a gang of men erecting Dorr Thickeners. This is a card obtained from actual practice, and shows the increased efficiency of a certain gang of five men in erecting these machines. As will be noted the first machine cost \$84.75 to erect everything above the foundation joists, including machinery. After completing the first, the gang immediately went on to the second tank and then to the third, showing an increased efficiency as they obtained more experience in erecting the tanks under these conditions. Fig. 3 indicates the same thing, that is, increased efficiency as the men "get into the collar."

| Stamp Stems Straightening | | | | | | | | | | |
|---------------------------|--------------|------|-----------------------------------|---------|----------|------------|---------------|------|------------|-----------|
| Date | Operation | Unit | Am't Ac. | No. Men | Time | LABOR COST | Supplies Used | Cost | TOTAL COST | COST UNIT |
| 10-8 | Black-1 stem | 2 | a b | | | 5.18 | | | 5.18 | |
| 10-9 | Smithing | 5 | abd | | | 13.08 | | | 13.08 | |
| 10-10 | and | 2 | abde | | | 13.47 | | | 13.47 | |
| 10-11 | Machine | 4 | abd | | | 10.12 | | | 10.12 | |
| 10-17 | Work | 8 | ab | | | 5.88 | | | 5.88 | |
| 10-18 | " | 2 | ab | | | 2.95 | | | 2.95 | |
| Individuals | | Rate | Maximum | 1.47 | Average | | | | | |
| a Weiss | | 4.50 | Maximum | 6.73 | Standard | | | | | |
| b Murphy | | 3.50 | REMARKS: Stamp stems bent in fire | | | | | | | |
| c Black | | 3.50 | | | | | | | | |
| d Parker | | 4.00 | | | | | | | | |
| e Mills | | 3.00 | | | | | | | | |

FIG. 4—CARDS FOR UNIT COST KEEPING

Eliminating Incompetent Men

Fig. 4 shows the cost of straightening stamp stems that were bent in a fire. The costs in this case were bound to fluctuate more or less with the amount of work necessary to straighten the stems. But there is one point that looms up in a very remarkable manner on this card. It will be noted that on October 10th a man lettered "e," whose wage was \$3.00 per day, evidently caused an enormous increase in the cost of that day. While the average for the entire time was \$2.81 per

stem, nevertheless on the day that "e" worked the cost jumped to \$6.73 per stem. On investigation it was found that "e" was somewhat of an agitator and decidedly a hard man to get along with. The natural conclusion from this card is that wherever "e" is working he not only accomplishes practically nothing himself, but interferes with the other workmen. It probably would be unjust to discharge him on the basis of this one card, but by switching him around to other jobs and finding the same thing to be true in all cases, it is certainly of vital importance to get rid of him.

These cards, as represented by Figs. 2, 3 and 4, may be used also for checking the work of a certain man; in making time-studies of a certain operation; or in keeping separate certain distributions. These cards are not necessary to a successful system of cost-accounting by various units, but are found to be a great convenience for all lines of special work. If these cards are kept for a period of several months and a file made containing several hundred cards, the information contained thereon will be of great value and extremely interesting.

It is not claimed that these cards are a cure-all for cost-keeping accounts, but the article is written with the primary intention of showing that a cost system must contain both the amount spent and the work accomplished, in order to be of any value to the operator in handling his work efficiently.

Denver, Colo.

The Construction of the Blast Furnace Stack

By J. E. JOHNSON, JR.

In the construction of the blast furnace the conditions to be met are diverse and to some extent conflicting. The efforts to meet these conditions have been almost innumerable, and types of construction of the most various kinds have been used for almost all portions of the furnace. These conditions we may proceed to outline.

RESISTANCE TO TEMPERATURE

Resistance to temperature is necessary to some extent throughout the furnace, but particularly in the hearth and bosh. The temperatures in these regions in the days of cold blast furnaces were moderate, probably around 2200 to 2400 deg. Fahr., and were resisted with some success even by natural refractories such as sandstone, which sometimes was used for the bottom and for the lining of the hearth and bosh of furnaces, even in coke practice, within little more than a generation.

But with the development of the furnace in the direction of greater output, and the more accurate control of the quality of the metal produced, the requirements have steadily grown more severe. Temperatures in the hearth and bosh in coke practice now probably range from 2500 to 2800 deg., these being the temperatures of the iron and slag as they come from the furnace, but it is almost certain that even higher temperatures exist around the tuyere zone. Probably 3000 deg. is not far from the working temperature prevailing in that zone in many furnaces. This approaches the temperature at which all materials lost a great portion of their resistance. If they do not melt they soften and are easily deformed or abraded.

RESISTANCE TO CHEMICAL ACTION

The lining of the blast furnace is probably exposed to more diverse chemical conditions than that of any other apparatus in industrial use. Iron itself, particularly before it is completely carbonized, when molten

is exceedingly active chemically and will dissolve or react with almost anything with which it comes in contact, especially substances in their elementary condition.

In the early days when sandstone was used as a refractory slags were relatively neutral—that is, they were what would now be called very acid. The requirements were then not nearly so severe in the matter of desulphurization, and as a consequence not much more lime was added than enough to make a fusible slag. But as the demand for a purer product has grown, more and more base has been added to the slag until now its chemical activity in most cases is intense. Few materials with which it comes in contact can long resist its solvent action unless protected by water-cooling and so kept below the temperature at which they can be dissolved.

As we go further up in the furnace we come to the zone in which the cyanides resolve themselves into different chemical compounds of great chemical activity in consequence of their composition and their nascent condition. We have here also an atmosphere consisting almost wholly of nitrogen and carbon monoxide at nearly a white heat initially, which gradually declines as the top of the furnace is approached. The reducing power of carbon monoxide under these conditions is enormous and is reinforced by the presence of incandescent carbon itself in the bosh of the furnace. Therefore, any metallic oxide in the lining which is subject to reduction by either of these agencies would be immediately reduced with consequent destruction of any refractory of which it composed a part. It is probable that many mysterious cases of bad results with fire-brick in the early days of their manufacture were caused by the presence of iron in them, which being reduced by the action of the furnace caused a disintegration of the brick and the early destruction of the lining.

The fume of blast furnace gas which gives the white color to the waste gas from a hot working furnace contains an appreciable quantity of soda and potash; these are liable to be precipitated by the decreasing temperature toward the top of the furnace, and to have a highly solvent action on the silica of the lining when this happens.

When zinc or lead, particularly the former, are present in the charge, even in almost infinitesimal quantities, they are vaporized and have a variety of actions on the lining which is almost incredible to one who has not torn out linings subjected to these conditions, as I have many times done. As an instance of the peculiar actions which this substance has, it may be illuminating to describe what I once saw in the bosh of a furnace blown out for repairs to the upper lining, the bosh being good and left intact.

The furnace was blown down so low that the stock had been burnt out below the level of the tuyeres, and crawling in through a cooler opening as soon as the little material remaining in the hearth could be cooled down sufficiently, I was astonished to see what looked like little stalactites, yellowish white in color, varying in length from two inches to six or more, and about a quarter of an inch in diameter at the base, standing up all over the bosh wall. When touched they fell to pieces and it was with great difficulty that some specimens were taken out whole. They were hollow, with walls only about as thick as wrapping paper, and very light and flocculent. Careful examination showed that they were the oxide of zinc which had been contained in the brick work of the bosh, presumably in some sort of state of solution, until after the pressure of the blast had disappeared. The oxide had then exuded, or more properly perhaps I should

say "sublimed" out of the brick into the solid condition, and, being carried upward by the air let in at the tuyeres to cool off the furnace, it formed these little stalactites.

In tearing down the brick outer walls of the older types of furnaces I have found large lumps of crystals of silicate of zinc in cavities in the lining at a distance of four or five feet from the nearest point to the inside of the furnace.

I have seen bricks taken out of the old lining apparently perfect in size and shape but somewhat dark in color. When lifted these would be two or three times the weight of ordinary bricks and if measured up carefully would be found to be half an inch larger in each dimension than the original brick from which they had grown. These were saturated with zinc oxide, which had swelled them as a whole without the least sign of cracking, the bricks being firm and, if anything, stronger than in their natural condition.

These instances are mentioned only to show the vast variety of chemical actions which the lining of the furnace must resist.

RESISTANCE TO ABRASION BY THE STOCK

About one-half, by volume, of the charge of the furnace in almost all cases is coke, one of the most highly abrasive substances known. In practically all cases also limestone is added to the charge in the condition of lumps sometimes of the size of a man's head or larger, but more generally crushed down at least to go through a 4-in. ring. The balance of the charge is made up of ore which varies from the soft condition of a plastic clay to the condition of one of the hardest of the common rocks, according to the variety. These materials are put through a modern furnace 90 ft. high, at the rate of something like 1700 or 1800 tons in twenty-four hours. The limestone and the ore as they approach the hotter zone are softened if not reduced to powder by the action of the gas upon them, but the coke remains firm and hard until it is burnt up at the tuyeres.

The abrasive action of such a mass of material even at atmospheric temperature would be considerable, but when it is remembered that in the lower portion of the furnace temperatures prevail which are above the softening point of any material available, it is obvious that the abrasion by the descent of the charge alone must present a problem to be reckoned with.

RESISTANCE TO ABRASION BY THE GAS CURRENT

The velocity of the gas through the shaft is exceedingly high, probably higher than is realized by those who have not actually estimated it. I believe in ordinary modern practice it is never less than 3000 ft. per minute, and more probably double that. This gas is necessarily filled with fine particles of material from the stock, which is in a constant state of agitation due to its descent, so that the fines are swept out of it almost as chaff is separated from wheat. These fines are picked up and carried by this great volume of gas moving at this high velocity. Most of the particles impinge on the solid stock, but many of them strike the furnace walls and exert thereon the action of the familiar sand blast. In this case also we must remember that the resisting material, at least in the lower regions of the furnace, is softened by heat so that much of its resistance is gone, and it becomes evident that we have here a form of destructive energy whose effects cannot be ignored.

RESISTANCE TO PRESSURE

It is absolutely necessary that the furnace be gas-tight in the same way, and as nearly as possible to

the same extent as a good boiler is steam tight. The pressures, it is true, are not as high as modern boiler pressures, but they range from 10 to 30 lb. per square inch in modern practice, probably averaging in Lake ore practice around 15 lb.

The effect of pressure in promoting reaction, especially when gases are concerned, and its effect in giving density and carrying power to the gas currents, are probably factors in the situation, but the principal point is that if this pressure be not resisted at every point gas will find the weak spot, and, traveling through it, will carry heat and chemical action to assist the destructive effect of the pressure. The pressure-resisting quality of the structure comes from the steel shell outside the lining, but this is quickly destroyed if the conditions prevailing within the furnace proper strike it, and with its destruction the whole structure fails. For this reason resistance to pressure is one of the prime conditions to be met.

Had the builders of those tiny furnaces which dotted the central Eastern states in the first half of the last century been shown these formidable specifications in advance of having practical knowledge of the subject they would undoubtedly have thrown up their

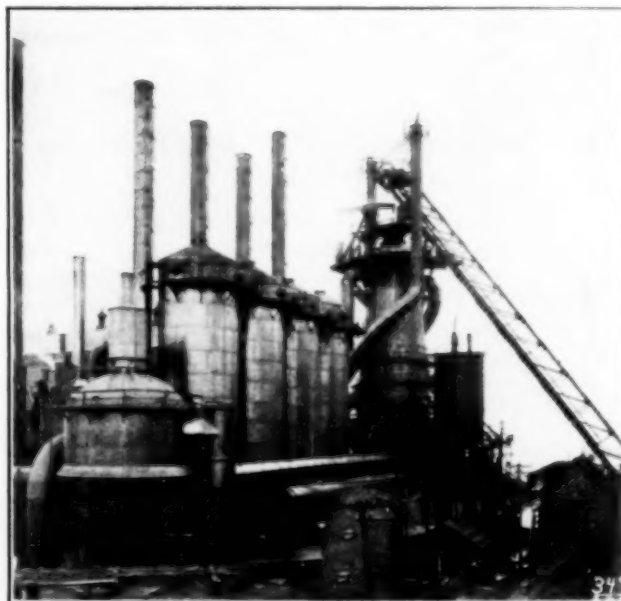


FIG. 1—MODERN BLAST FURNACE STACK WITH STOVES AND DUST CATCHERS. BUILT BY WILLIAM B. POLLOCK COMPANY

hands and ceased all efforts to meet such apparently impossible conditions. But, as a matter of fact, they had not the disadvantage of this knowledge, for disadvantage in their case it would have been, since the practice to which they were accustomed involved difficulties constituting only a fraction of those outlined above. This was due to the lower temperatures and the lower rate of driving, with its reduction of abrasion both by gas and by stock, and perhaps most important of all they did not dream of such pressures as we now consider right and proper.

In happy ignorance, therefore, of the conditions which their successors would have to meet, they built stacks of stone, truncated pyramids, one side of the base almost as long as the stack was high. In the earliest days all these were built, as I have already described, against and into a hill. Only one tuyere was used. No distinction was made between supporting structure and lining. The stack was simply a truncated pyramid 20 to 40 ft. high, with a hole some

6 or 8 ft. in diameter through it, hardly different from a square chimney with a round flue, except of more squatty proportions. In one side was an archway into the stone work which gave access to the single tuyere and the fore-hearth which I have previously described.

This simple pile of masonry resisted the pressure of

each successful step helping toward the next, and with slow, painful and costly progress we have passed from those primitive conditions to those prevailing to-day.

Two of the earliest changes were the substitution of fire-brick for the lining of the stack and the provision of an archway in each side of the structure with a tuyere in each arch instead of only one. More probably in many cases three of the arches were used for tuyeres; in the fourth the tuyere was left out in order to make room for the fore-hearth, tapping hole, etc. Gradually as the proper shape of the furnace was evolved the hearth structure became separated at the base from the piers of masonry which supported the whole stack, and finally it became evident that it was desirable to increase the distance between these so as to provide greater access to all portions of the hearth. In course of time also the stone stack with its binders of hewn timbers gave way to a brick stack banded with flat bands like a tank, the structure passing from square to round in its exterior shape, the lining being of fire brick and fully differentiated from the stack proper.

About 1860 this structure was superseded at one of the Lake Champlain furnaces by a shell riveted up of plate iron standing on cast iron columns, the prototype of the structure used to-day and lined with fire brick.

The photograph of a modern furnace is shown by Fig. 1. The stack is at the right. A section drawing of another but similar furnace with its hoist is shown in Fig. 2.

It will be seen that there is a foundation of concrete 13 ft. below the ground level and 39 ft. in diameter, upon which the whole structure rests. An annular foundation of brick work upon this supports the bases of the columns, ten in number, each 25 ft. high and 2½ in. thick. Upon these columns rests a heavy ring of structural material better shown in detail in Fig. 3, and to this mantel is riveted the shell of ¾-in. steel plate, 36 ft. in

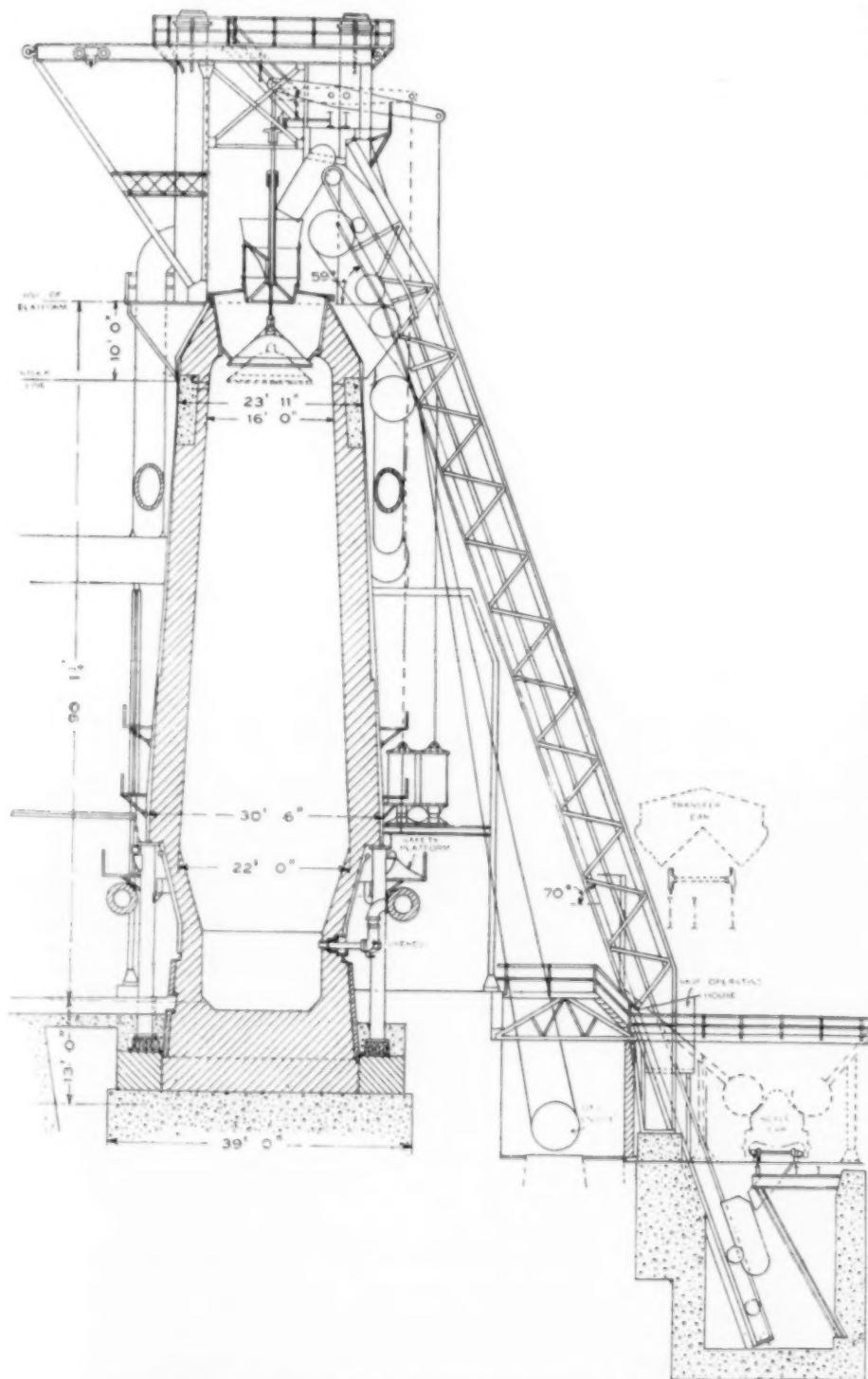


FIG. 2—VERTICAL SECTION OF "A" FURNACE, BETHLEHEM STEEL COMPANY

the blast, the heat of the combustion, the abrasive action of the stock and the chemical action of its heterogeneous contents.

The gradual increase in output from those days to our own brought changes in construction, and these in turn permitted greater outputs which again required other changes of construction, and so, with

diameter at the bottom and 23 ft. 11 in. in diameter at the top. This shell is riveted up with the same class of workmanship as that used in the best steam boilers. Within this shell is the brick work about 4 ft. thick at the level of the mantel and maintaining nearly this thickness all the way to the top. Below the top of the mantel the brick work is thinner down to the tuyeres

and then below the tuyeres thicker again, finally uniting with the furnace bottom, which consists of some 8 or 9 ft. of solid fire-brick work on the concrete foundation.

This structure is in broad outlines typical of the standard construction of to-day, but the variations of detail are almost as numerous as the individual furnaces. It is impossible to describe all these variations individually, but by dividing the furnace into zones we may deal in some detail with the conditions to be met and the approved forms of construction in each. The zones in which the furnace should be divided for this purpose are the hearth and bottom, the tuyere zone, the bosh, the shaft and the top.

The Hearth and Bottom

The necessity of resistance to chemical action for the furnace as a whole has been briefly described above. This is particularly necessary in the hearth and bottom because these actions are the most intense in that region and because the consequences of failure of these structural parts are so disastrous.

The hearth of a furnace just before the cast time contains normally 60 to 80 and may readily contain 150 tons of molten iron and 20 to 40 tons of slag. The effect of pressure in intensifying chemical action has already been mentioned and in the hearth this condition is exaggerated by the fact that the pressure due to the depth of metal and of slag on top of it, is added to the pressure of the blast which, of course, is highest at the tuyeres. We may have, therefore, a depth of 7 or 8 ft. of metal with 2 or 3 ft. of slag laying over it, exerting a pressure of 3 lb. per square inch for each foot in depth of iron, and about 1 lb. for each foot in depth of cinder, so that we can easily have a liquid pressure of 25 or 30 lb. in the bottom of the furnace in addition to the 15 lb. of blast pressure in one properly working or perhaps 30 lb. in one working irregularly, so that the total pressure in the hearth of the furnace may easily approach 50 lb. per square inch.

If this be not firmly resisted and the least yielding takes place a crack will occur in the brick work and the metal instantly following this crack will approach the outer wall of the structure which supplies its physical strength, and if it succeeds in reaching this at some point not completely protected, the stream of liquid iron will quickly cut a hole through the iron or steel jacket around the brick work, and the stream of metal flowing through this hole will enlarge it with a rapidity which is almost beyond belief except by those unfortunates who have had experience with this action.

In one case which came under my personal experience the stream of iron cut through the hearth jacket a hole elliptical in shape and about 3 ft. long by 1 ft. high, with its long axis horizontal. Even if the hole be many times smaller than this the entire contents of the furnace are ejected through it under the action of their own weight, and the pressure of the blast in a few minutes, and this vast mass of molten material with the tremendous cutting power which flowing streams of such molten material have destroys anything metallic in its path in short order, and in very many cases has cut and seriously damaged the columns supporting the furnace structure. If this runaway body of metal strikes a wet place on the floor of the cast house or on the ground an explosion is almost certain to result which may be disastrous in its consequences. Furnaces have even been put out of blast by the results of such breakouts, and even worse cases are only too numerous in which men around the furnace have been injured or killed by such accidents.

For this reason the construction of the hearth and bottom of the furnace has received an enormous amount of consideration and experienced furnacemen are quite generally of the opinion that any reasonable amount of money spent in securing a construction immune from breakouts is well invested, a conclusion with which I thoroughly agree.

A construction which in general meets this object has finally been developed, and is illustrated in Fig. 3.

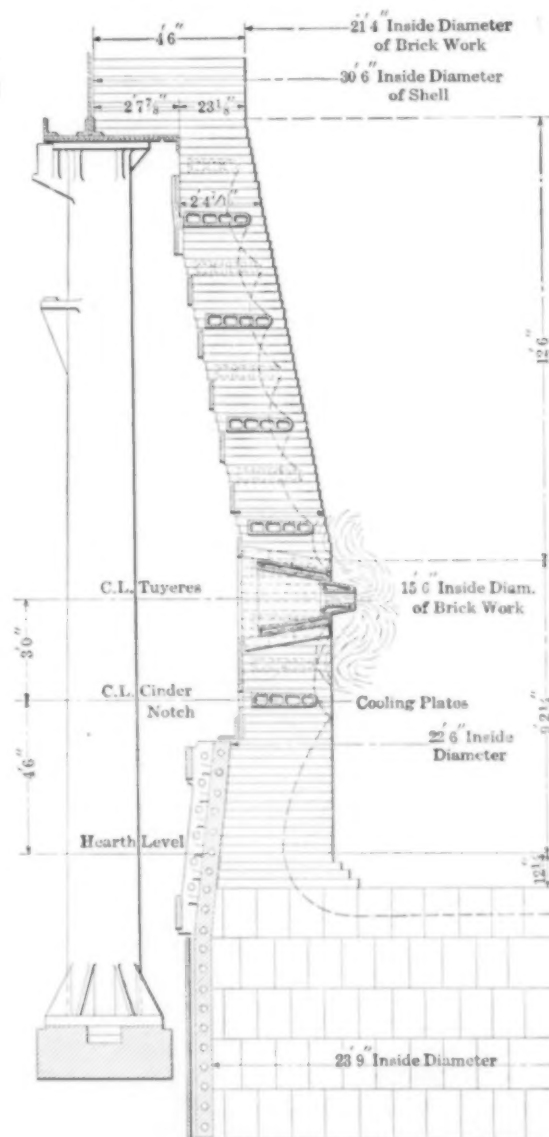


FIG. 3—HEARTH AND BOSH OF INLAND STEEL COMPANY'S "B" FURNACE

which shows in vertical half section the lower part of the blast furnace of the Inland Steel Company at Indiana Harbor, Indiana.

The metallic part of the construction consists of a series of steel staves with coils of cooling pipes cast in them, which extend from about 4½ ft. above the bottom level of the furnace to about 6 ft. below it. These are not fastened to each other, but are surrounded by an outside jacket. The lower part of this consists of a heavy rolled steel jacket riveted together with internal and external butt straps, no pains being spared to make the strongest joint possible, this jacket is separated from the staves by a small expansion space filled with yielding material.

The upper part of the staves is surrounded by a

cast-steel jacket which also has water-cooling pipes cast in it. Its staves are fastened together by links shrunk onto the projecting lugs. They are of great thickness and, being made of steel castings, are enormously strong, but are further reinforced by rolled steel bands about 3 in. thick by 1 ft. in height around the top and bottom. The edges of the segments of this upper cast steel jacket are carefully planed to make a perfect joint, it having been found by experience that if there be an open joint in the jacket no matter how solidly the brick work may be built inside it, sooner or later the iron is likely to worm its way through the brick work and reach this crack. The instant the iron reaches it and begins to flow through it, the crack enlarges by the cutting power of the metal and soon a full-fledged breakout takes place which nothing can stop until the furnace is empty.

For this reason no pains or expense are spared to make hearth jackets not only strong enough to resist the expansion of the brick work and to prevent their rupture by this action, but also to make them of practically air-tight construction.

It was formerly considered by many furnacemen exceedingly dangerous to have internal water cooling below what is known as the iron line—that is, the height to which the iron may rise in the ordinary course of operation—this height being normally some 2 or 3 ft. below the center of the tuyeres, though in case of trouble the iron may rise up to the tuyeres. The reason for this objection to water-cooling is that a current of iron flowing with considerable velocity will cut a water pipe or other cooling apparatus with the water flowing through it, since it is impossible for the water to remove the heat as fast as the stream of iron supplies it. When a cooling member is cut in this way explosions are almost certain to occur, and these are more disastrous the more confined the location in which they take place. Many frightful accidents have occurred through the cutting of water-cooled parts by molten iron.

When the joints in the outside jacket are absolutely tight such a flow of metal cannot start, and as it is only a flow which possesses this tremendous cutting power, the cooling pipes are not endangered by this action when there are no crevices through which the iron can flow past them. By the combination, therefore, of the tight jacket, and the water-cooling staves inside it, the danger of breakouts which formerly was almost the worst dread of the furnaceman's life, have been reduced to a minimum, almost to a negligible quantity.

It will be noticed in Fig. 3 that there is a thickness of three feet of brick at the top of the hearth jacket, and that this increases toward the bottom. This is for the reason that the high velocity at which the blast is injected through the tuyeres gives it a mushrooming effect indicated in Fig. 3, which throws it back against the wall around the tuyeres and tends to cause severe cutting, augmented by the heat and chemical activity of the molten iron and slag. These jointly tend to cut away the hearth as shown in dotted lines, but by having an ample thickness of brick and having the line of water-cooling of a much larger diameter than that of the nose of the tuyeres, the water-cooled surfaces have a better chance to overcome this combined action, so that furnaces built in this way cut back to a certain distance and then stop, whereas if the outside diameter of the hearth were made smaller in relation to the tuyere diameter the probabilities are that it would eventually give way under the joint attacks of these three influences.

It was formerly thought that every furnace had to have one or two breakouts when it started to working

properly soon after it was blown in, and in the days when furnaces were small and the quantity of iron in them at one time was only a few tons, this, while a bad condition, was endurable, but, as furnaces and their outputs have grown and the amount of metal released by a breakout has increased, it has become increasingly necessary to solve this problem almost irrespective of the cost of the construction. The evolution of the general type described is the result of necessity.

THE DITCH AROUND THE HEARTH JACKET

There is ordinarily a ditch around the outside of the hearth jacket extending from just above the base of the columns, which are bricked in solid, up to about a foot above the hearth level, and practice in regard to this ditch has varied greatly. It is customary to use this to carry off the waste water from the tuyeres, coolers, etc., and formerly these ditches were kept full of water to their tops, with the idea that this furnished effective cooling of the hearth jacket and tended to prevent breakouts. But in order to keep the ditch full of water its outlet must be dammed, and when this was done if a breakout did occur the molten iron filled up the ditch to the level of this dam, part way or even all the way around the furnace, and when cold had locked itself between the columns and the hearth jacket, whence it was almost impossible of removal.

At one time the practice prevailed of filling the ditch to the top with large lumps of limestone piled in as loosely as possible, then if a breakout occurred the decomposition of the limestone by the heat and the subsequent slacking of the lime tended to crack apart the mass of iron, which, of course, was much reduced in quantity and solidity by the presence of the lumps themselves. This practice is an improvement, but the practice of carrying the ditch full of water is itself going out of vogue to some extent, and personally I would never have the water in the ditch more than a couple of inches deep if it could be avoided. This enables the ditch to be kept open to the bottom, and if a breakout occurs the molten iron will run out the outlet and leave the ditch comparatively free. Moreover, more effective cooling may be obtained by the spray from a small circle pipe causing a thin film of water to trickle down over the hearth jacket than can be obtained with a large body of standing water. This has often been established and is another illustration of the principle that rapid circulation has as much to do with heat conduction as the amount of surface and conductivity of the material involved.

Allowing the outlet from the ditch to carry off the iron in case of a breakout has some disadvantages because the iron itself will run along the bottom of the ditch underneath the water for long distances, even in quite small quantities. I have known it to go 60 or 70 ft. and plug up the screen over the waste opening into the sewer so as to create a fearful nuisance.

To meet this situation two expedients are available, one of which is extremely simple and should always in my judgment be used. This consists in having an auxiliary outlet from the ditch normally kept closed and designed to discharge at some point sufficiently removed from the furnace so that any iron carried off by it may do as little harm as possible. This ditch may be closed either by a hand-operated gate or by a thin lead plate. The latter will cut off the flow of water effectively, but will melt in case iron strikes it and open up the emergency outlet. This should preferably be placed lower than the main outlet so as to drain the iron completely away from the latter. The

use of this expedience once saved a shutdown of many hours at a plant formerly under my management.

The other expedient is somewhat more expensive. It consists in building a large chamber or cistern in the bottom of the outlet ditch, which is covered over by the cast house floor plates under ordinary conditions, and stands full of water all the time, the wastewater current simply passing across its top, but if a breakout occurs the iron will run into this cistern and has to fill it up before it can go on through and make its way into the outlet sewer, the plugging of which constitutes a calamity of no mean order.

It is frequently customary to have the ditch around the furnace interrupted by a solid structure of brick on which the iron-trough beneath the tapping hole is supported, but I do not like this construction, as the heat is drawn through the hearth jacket by the poulticing action of this brick pier and the circulation of water is cut off by it. Moreover, in case of a breakout the presence of this dam in the ditch prevents the iron from draining away in that direction and may result in permanently filling the ditch with a mass of iron at that point.

By riveting a pocket a little larger than the outside of the iron trough air-tight on to the front of the hearth jacket the trough can be set down into this and a joint made between the two with cement, the water can then rise practically to the bottom of the iron trough without any danger of getting into it, and yet have an absolutely free circulation around the base of the hearth jacket at this point, which probably needs it more than any other.

The Tuyere Zone

This is the zone between the top of the hearth jacket and the bottom of the sloping bosh. Various styles of construction have been adopted for this, as for all the other regions of the furnace. One of these which had much vogue at one time was the use of a heavy cast-iron or even cast-steel tuyere jacket with cooling pipes cast in it, and with openings cast through it of the size required by the coolers, no internal cooling by cooling plates being used.

This construction and all others which depend on external cooling in this zone are in my opinion faulty for the reason that the tuyeres must project a considerable distance into the furnace. If they did not, what I have called above the mushrooming effect would rapidly destroy all the parts adjacent to them; therefore, we have first the hollow-walled cooler as a sort of second line of defense which projects into the face of the brick work. Then fitted into this and projecting about a foot beyond it we have the tuyere itself, its nose being some $3\frac{1}{2}$ or 4 ft from the exterior of the brick work, which is literally on the firing line.

The mushrooming effect of the blast, if this zone were without any but exterior cooling, would soon eat away two or three feet of the face of the brick work, which would leave the heavy coolers carrying the tuyere without adequate support. This in turn would allow them to drop down so that instead of directing the blast in horizontally, as they should, it would be blown downwardly into the bath.

To overcome this and to protect the zone around and between the coolers from this intense mushrooming effect, cooling plates are used as shown in Fig. 3. These are hollow plates of copper, or copper with one or two per cent. of tin to make it cast more readily, with a taper in the vertical plane, as shown, and also in the horizontal plane. These are supplied with water from the water-cooling system and a constant circulation kept up through them the same as in the tuyeres.

They are built into the brick work, but on account

of the taper above mentioned can be withdrawn by means of lugs provided in their rear or outer surfaces for that purpose. These have a great cooling surface and corresponding protective power for the brick work around them. They increase the resistance of the brick against the action of the fire, and the brick to a great extent protects them from the direct attacks of the latter, although frequently they are directly exposed to it, as are the tuyeres, but able to resist because of the activity of the water-cooling, in exactly the same way that the fire box of a locomotive is able to withstand the intense combustion of the fire within it because the thin plates which constitute its inner surface are so completely cooled by the water around them.

It will be seen that these cooling plates with their ability to withstand the direct action of the fire, protect the fire-brick work underneath and around the coolers from the attacks of the iron, the slag and the mushrooming effect of the blast, and so enable these to maintain their correct position throughout the campaign.

In order to supply the element of strength against the internal pressure of the furnace two constructions are possible. Either bands can be passed around the furnace just above and just below the cooler openings, leaving the space between these bands unprotected, or the bands may be connected by vertical buckstays which protect the intermediate space. The construction which I like best of all, however, is to make a solid jacket of steel plate, as shown in Fig. 3, with the flange at the base resting on the top of the hearth jacket, with holes cut through it at the points where the cooler openings and the cooling plates come. This supplies the means of holding all the brick work to its place, which is necessary, for, in the absence of such protection, it is surprising how small a mass of unbound brick work will detach itself from the rest and work out of the furnace under the action of expansion, pressure, etc.

The Bosh

This divergent cone which begins at the top of the tuyere zone has received attention at the hand of a vast army of engineers and furnacemen, and many solutions of the problem of a suitable construction have been attempted. The divergent shape of this portion of the structure and its relative lack of solid foundation upon which to build a patch if it fails, combined with the scouring action of the blast traveling up it, and of the semi-reduced iron and scouring slag travelling down it, have made the problem of maintenance of this part of the furnace a difficult one.

One of the most commonly used constructions is that shown by the upper portion of Fig. 3. It consists of several rows, in this case eight, of cooling plates, those in one horizontal row alternating in vertical location with those in the rows above and below it. In other words, the plates in each of the eight horizontal rows are not vertically above one another, but are staggered for reasons of mechanical strength, because the plates are very much weaker against compression stresses than the brick work, and if they were all in one row might be crushed by the expansion of the boshwalls due to the heat. By having them in alternating rows larger masses of brick work intervene between them, making a sort of series of arches which do not readily crush. Moreover, if all these cooling plates were arranged in vertical rows, the brick work between these being relatively without protection would be scoured out by the erosive actions I have mentioned.

By staggering the plates vertically the space between a pair in one row is protected to a great extent by the plate in the other rows above and below that space. This construction is shown in Fig. 4. Just above the bustle pipe portions of two rows of cooling plates and

their vertical staggering may be quite clearly seen.

The cooling plates must be protected from the weight of the brickwork above them and this is done by one of two methods. Either a flat arch is turned in the brickwork above them or a cast-iron box is built into the brickwork which projects in from the outer wall about one-half or two-thirds the length of the cooling plate, which is inserted through and protected by this box. Both methods are good but the brick arch is much cheaper and just as good for all practical purposes, so is to be preferred.

Circumferential strength is supplied by very heavy bands of steel running around the bosh between the rows of plates. This makes a good strong substantial construction, but in addition to being very expensive on account of the great quantity of copper castings re-

plates, but in either event the whole mass sloughs off into the hearth and having no time to be treated by the heating and reducing action of the ascending gas is precipitated into the hearth in a half raw condition with resulting ruin to the iron and slag already formed therein, and the partial chilling of the furnace, perhaps to a serious extent.

It is these steps and the consequent irregularity of the work of the furnace at times which has led some furnacemen to abandon this type of construction for one whose wearing surface should be smoother and more regular. This result has been sought in some cases by building up a water-cooled bosh jacket of cast-iron segments as shown in Fig. 5. These segments as shown are strongly bolted together to supply the necessary strength to resist the pressure, and then re-

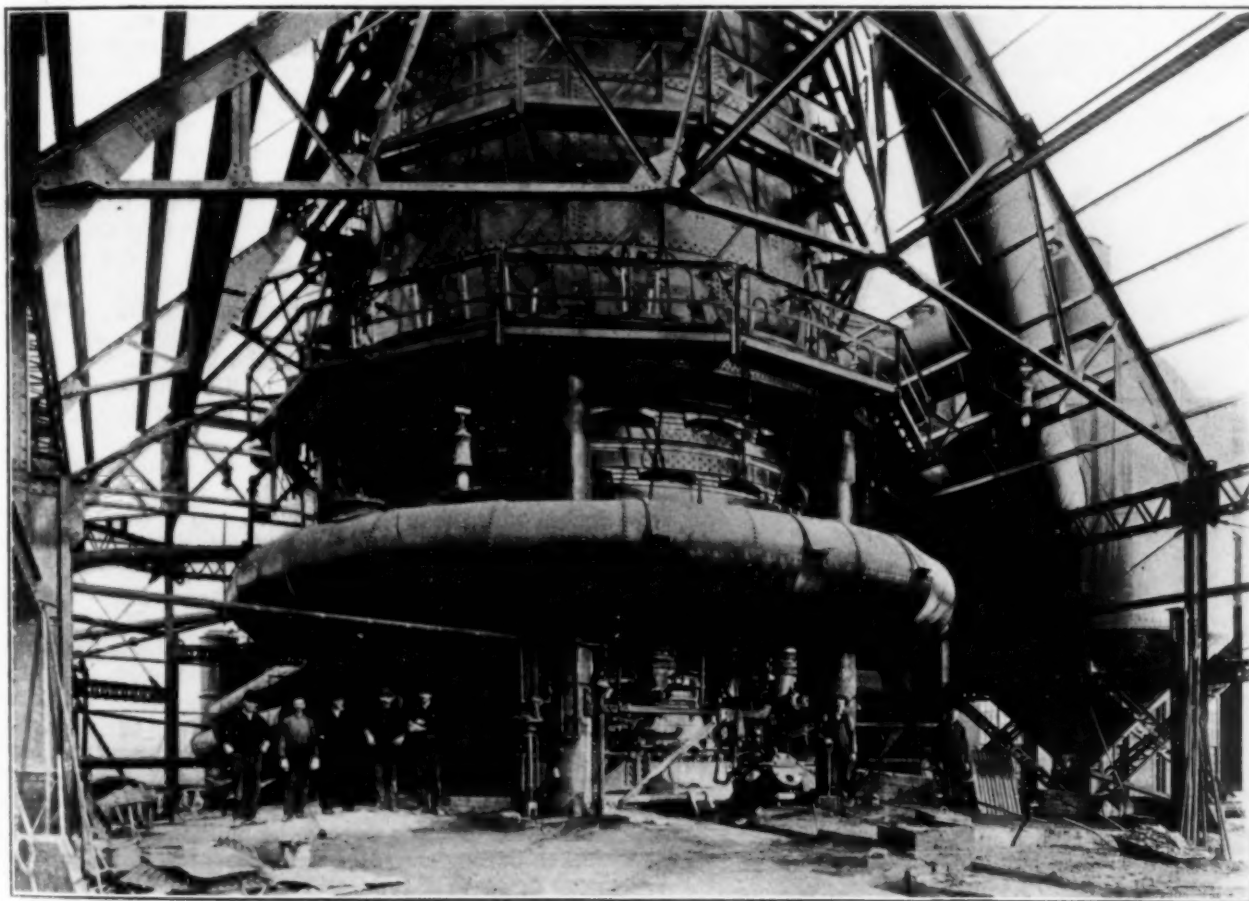


FIG. 4—LOWER PORTION OF FURNACE SHOWN IN FIG. 1

quired, it is liable to one serious fault. This is that the erosional influences I have mentioned cut out the brick work between the plates and leave the noses of the latter sticking out into the furnace almost like a flight of steps. I have tried to illustrate this action by the dotted lines in Fig. 3 and can state most emphatically that the conditions shown by this sketch represent only a fraction of the erosion that I have seen in actual practice after a campaign of only a year or two.

When the action has proceeded to the extent indicated or further, the shelves formed by the projecting noses of the cooling plates make ideal lodging places for half molten slag and such materials as it cements together, and such a mass builds up on the noses of the plates at times with considerable rapidity. Then a change in the condition of the furnace comes about or the accumulations are no longer able to maintain themselves on the narrow footing offered by the cooling

ceive a thin lining of brick, its thickness depending upon the opinion of the furnacemen as to what is necessary, but commonly from nine to eighteen inches. This is an expensive construction and requires careful machining throughout, because if the least crack exists the gas will blow out through it with destructive effect and on account of the crack being small it is almost impossible to get anything in the nature of a clay stop to stay in it.

A third type of construction consists of a bosh jacket made entirely of steel plates and cooled solely by external sprays. This can be made an absolutely airtight job of boiler work, thus eliminating any possibility of gas leakage such as I have described, while the cooling by means of a continual film of water on its exterior surface produced by sprays is one of the most efficient forms which can be obtained in any way whatever, a much greater surface being exposed to the

cooling action of the water than in the case of the cast-iron built-up jacket.

One feature of a jacket of this kind must receive the most careful attention. It must be as near absolutely smooth as it can be made by good workmanship. The rivets must be countersunk on the outside and driven down absolutely flush so that a film of water will travel over their heads without any interruption, and in general everything must be done to remove even the slightest obstruction from the path of the water film, because this film travels down the surface with a considerable velocity and even a minor obstruction will throw it off leaving a dry spot below the obstruction. This dry spot becomes hotter than the rest of the jacket and causes contraction strains and in time cracks result, while if it be a large one the lining on the inside of the jacket will melt off and the jacket itself will then be exposed to the assault of the streams of iron and slag running down inside it, which will soon cut a hole through it. Such holes are almost impossible to stop

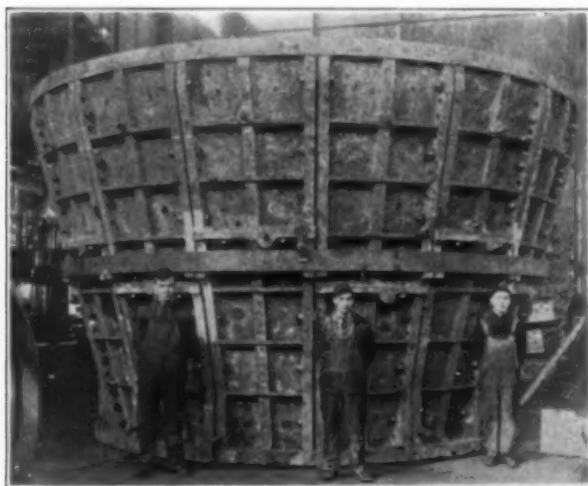


FIG. 5—SEGMENTAL BOSH JACKET BUILT BY BIRDSBORO FOUNDRY & MACHINE COMPANY

without a long shutdown on the furnace to enable a patch to be put on, and as this can only be done with patch bolts it is never anywhere near as good as the original jacket.

This is one of the places where an ounce of prevention is worth a ton of cure, and the only proper course is to make it impossible for a dry spot to form on one of these jackets.

Fig. 6 shows a furnace reconstructed according to the plans of the writer with a jacket of this type in which absolute smoothness was obtained by welding it up with an oxy-acetylene burner, then chiselling off the roughness at the joints and grinding it down smooth, an operation which took little time and cost a relatively small amount, something like a couple of hundred dollars above the cost of boiler work.

This jacket was flanged out at top and bottom to avoid the necessity of riveting angles on it to make connections to the mantel plate above and to the trough at its base. By flanging the metal out bodily these riveted joints are avoided.

Water is sprayed into the top of this jacket by a circular spray pipe divided into eight sections, each of these being connected to the water supply separately, and each of them also being in duplicate, only one being used at a time. If one becomes obstructed or fails the other can instantly be put on. This feature, as a matter of fact, is used only when it is occasionally necessary to clean out one of the sections, but it is a

convenience at that time and contributes to safety at all times and is well worth the trifling expense.

Some care should be taken to supply the water to these sprays under a very moderate head and make the holes in the spray pipes fairly large. They are then much less likely to become obstructed by small threads of pump packing and like and can be made to deliver the water exactly at the top line of the jacket with a minimum of spattering, the water thrown on to the jacket flows down it in a smooth film and the spatter is caught by the annular funnel shown about half way down the jacket, which is not riveted to the latter but comes in contact with it through a serrated edge at the bottom of the funnel. This serrated edge gives sufficient flow at every point around the circumference which would not be the case if the bottom edge of the funnel were straight as the contact would be close enough in that case to cut off all flow in places.

By having the funnel hung from above by independent hangers it is possible to adjust the location of its bottom edge in relation to the jacket with small wedges to regulate the flow and get it uniform around the furnace, which could not so readily be done if the two were rigidly connected. Moreover when the funnel is supported from the jacket this involves rivets in the jacket for the funnel brackets and below these rivets it is almost impossible to avoid having a dry spot as above described.

This jacket was so extremely smooth and worked so admirably in service that the intermediate funnel could probably have been dispensed with entirely by widening out the bottom trough a little more and perhaps putting some flanged extensions around its upper edge to catch spatter.

The trough as shown projects out beyond the base of the funnel, but should have been made three or four inches wider than it is because some of the drops from the bottom edge of the funnel are deflected from the vertical line by capillary attraction and fall outside the line of the trough which cause disagreeable spattering down below.

When using a construction of this type it is not only possible but far preferable to use a very thin brick lining in it, because the brick being cooled only from the outside will rapidly wear down to that thickness at which as much heat is carried away from their bases as the currents of molten material and gas supply to their front surfaces. This is only a few inches and if three feet of brick were to be built inside such a bosh jacket in the course of a few months it would all be gone down to a few inches, exactly the same as if it had started at one foot or even nine inches in thickness. Consequently if the furnace were the correct shape to begin with it obviously could not be so with three feet of brick scoured off the bosh all around, therefore the thing to do is to put in only as much brick in the first place as the furnace may be expected to leave there after it has settled down to regular work.

In coke furnaces using a bosh of this type I have several times used only nine inches of brick with very satisfactory results, and in the furnace shown by Fig. 6 which was to use charcoal and therefore much easier on the lining than a coke furnace, I used only four and one-half-inch bricks made up specially as circle bricks to fit the curvature of the bosh. This furnace was blown out on account of commercial conditions after a campaign of about a year and a half, and two inches of the original brick was still left. The judgment of the furnacemen was that it was as good as new.

A point about this construction which must not be overlooked is that the lining in this portion of the furnace is practically self-renewing. If the brick were

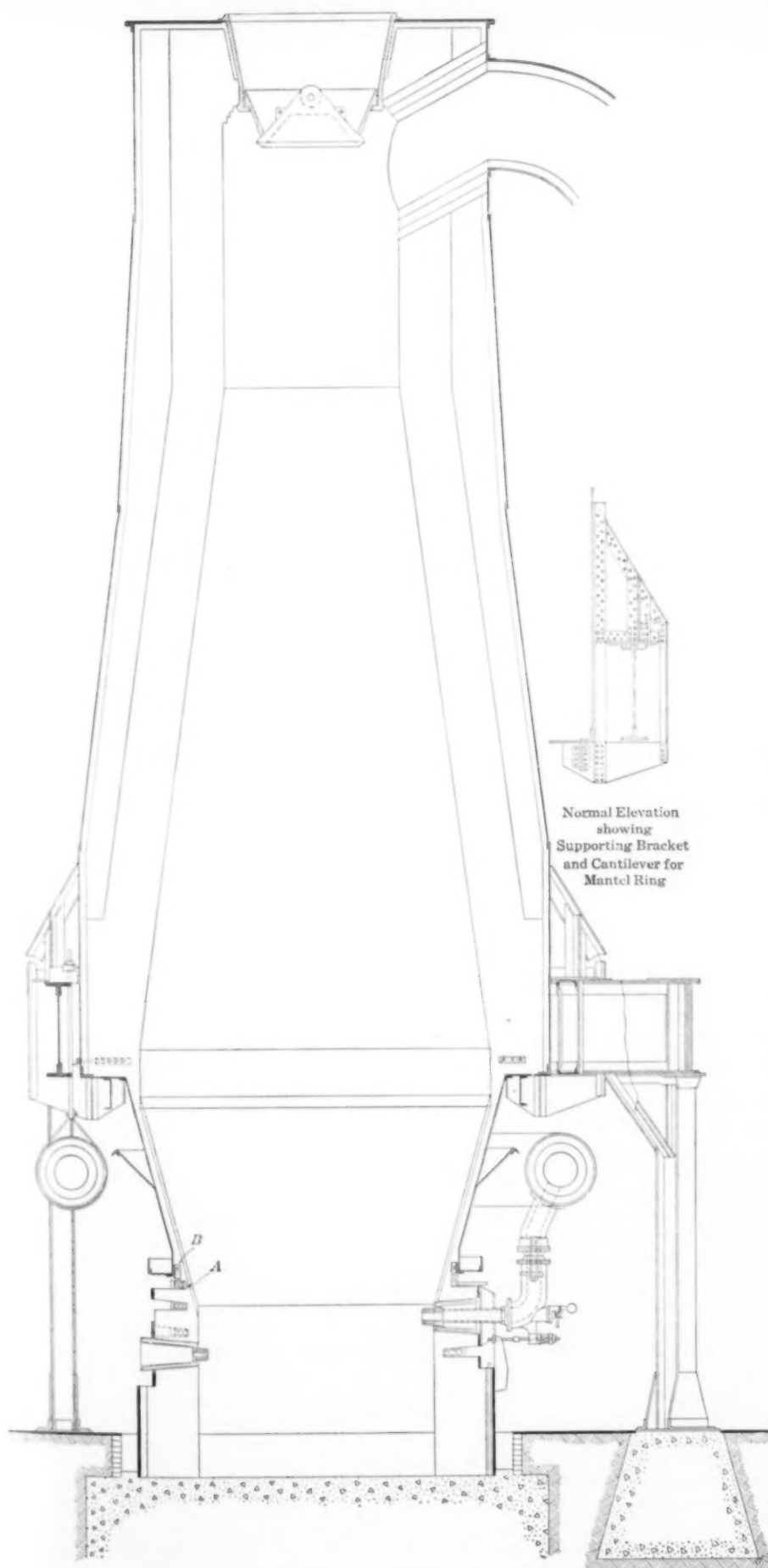


FIG. 6—CHARCOAL FURNACE, SHOWING STEEL BAR JACKET CONSTRUCTION

all scoured off the jacket clean by bad slag or bad work of the furnace, and the water-cooling were maintained, within a few hours the furnace would have built back itself a lining of slag, carbon dust, etc., just as resistant for its purposes, if not more so, than the fire-brick initially used.

This condition arises from the fact that this portion of the furnace converges toward the bottom, and that any material chilled on it tends to stay because of its conical shape. This is a feature of much importance which does not exist in any other portion of the furnace.

Owing to the small quantity of brick in the lining of the bosh in this construction it is without much compressive strength and differs in that respect from the cooling plate construction of Fig. 3 in which a considerable portion of the weight of the furnace structure is carried on the hearth and bosh walls when the latter are heated up by expansion. With the steel-plate bosh construction this must not be allowed to happen as the thin brick lining would quickly crush and the steel jacket buckle with disastrous consequences under compressive stress. It is necessary, therefore, to provide a sort of expansion joint in which the expansion due to the heating of the brick can be taken up without objectionable consequences. That is accomplished in the present construction by making the lower portion of the bosh jacket proper, cylindrical and putting inside it a set of cast iron water-cooled housings or blocks through low opening in which project cooling-plates as shown at A. These cast-iron housings and the cooling-plates are supported on the heavy brick structure around the tuyeres which extends up from the bottom. The bosh jacket and its lining on the other hand are practically suspended from the mantle.

When expansion takes place the cylindrical portion of the bosh jacket slides down over the water-cooled housings, and if the lining is cracked or broken by this action, the crack is at once sealed by cinder running down over the

surface and chilling against the housing and the bosh jacket.

In order to avoid the necessity of lugs and fastenings on the housings they are held together by the band B around their tops, this band being protected from burning by the cold bosh jacket just outside it and the water-cooling within the housing.

The water pipes for the cooling blocks A were brought out at the bottom so that the maximum of expansion could take place without shearing off these pipes, which has been known to happen in a construction of this kind where this provision was not made for it. Even in this case it would have been better if the space between the bottom of the trough and the top of the solid brick wall had been made three or four inches higher.

The water-cooled housing and the cooling plates projecting through them perform a double function, they protect the *tuyeres* and coolers below them for the scouring action of the streams of iron and cinder and prevent the spaces between the coolers from being scoured out and so weakening the tuyere zone. Secondly they form a water-cooled shelf at the foot of the bosh slope which supports the lining of the latter and forms a ledge on which a new lining can start to form in case the old one is scoured off by irregular furnace work.

Both these functions are of great importance and some portion of the construction to perform them must be supplied if this type of bosh is to give the long and useful service of which it is capable. When properly designed there is no doubt that this type of bosh construction will give absolutely satisfactory results in furnace operation on account of the perfectly smooth slope of its working surface and the complete absence of steps on shelves, at a cost of construction which is literally only a small fraction of that of the cooling plate or water-cooled stove construction.

(To be concluded)

Colorimetric Estimation of Gold in Cyanide Solutions

It sometimes happens that conditions of precipitation are disturbed temporarily, and frequent determinations of gold in barren solution are desirable in order to control the precipitation process. Time is not available for the ordinary assay, and a rapid method is required which can be performed by the foreman or shiftman in charge of the work. In discussing a paper on the metallurgy of the Homestake ore, presented to the Institution of Mining and Metallurgy by Messrs. A. J. Clark and W. J. Sharwood,¹ Mr. Charles B. Brodigan recorded such a method devised by Mr. Dowsett, reduction officer at the Brakpan mines, South Africa.

With slight modifications, the method of Mr. Dowsett has since been adopted at the Homestake mill for testing barren solution, and we are advised that by its use the mill foremen are able to detect with surprising accuracy variations of 1 cent per ton, in solutions carrying from 1 up to about 15 cents per ton. Seven minutes is sufficient for a test, and the method is extremely useful when conditions of precipitation are unsettled and frequent determinations necessary. No standards are used, the grade of solution being estimated by the depth of color obtained. The color for a 1 or 2-cent solution is very faint, but is readily detected after a little practice. For successful work it is important that the cyanide solution used be of the highest possible strength.

In his original contribution Mr. Brodigan states:

¹ *Transactions*, I. M. M., Vol. XXII (1912-13), p. 190.

"If gold is present to the extent of 0.02 dwt. (2 cents) per ton of the original cyanide solution a very slight coloration will be perceived in the liquid; 0.03 shows a slight yellow; 0.04 slight pinkish-yellow; 0.06 strong pink; 0.08 the purple of Cassius."

The Method

Details of the method as employed at the Homestake are as follows:

Reagents required. Zinc dust, sifted through 200-mesh sieve.

Hydrochloric acid, concentrated C. P.

Nitric acid, C. P., 1 acid; 2 water, in dropping bottle.

Lead nitrate, saturated solution, in dropping bottle.

Sodium cyanide, saturated solution.

Tin chloride, about 12.5 per cent crystals + 10 per cent concentrated hydrochloric acid.

Place about 500 cc of the sample to be tested in a light-colored, sample bottle having a very slight shoulder; a quart beer bottle is about the right size. Add a measured quantity, 10 to 15 cc, of saturated sodium cyanide solution; two or three drops of saturated lead nitrate solution; and from 1 to 2 grams of zinc dust. One gram of the dust usually will be found sufficient. Stopper the bottle with the thumb and shake violently for at least two minutes, or until the precipitate is completely coagulated and will settle rapidly.

Invert the bottle over a casserole and allow the precipitate to settle. Remove the bottle and decant the clear solution from the casserole. Add hydrochloric acid to the precipitate, drop by drop, until the reaction ceases, and then add a few drops in excess. Add three to five drops dilute nitric acid, heat and evaporate to a volume of 1 or 2 cc. Transfer the solution to a small ($\frac{1}{2}$ -in.) test tube, cool, and add about 1 cc tin chloride. A purple color indicates gold.

With low-grade solutions the tube should be allowed to stand a minute or two to bring out the full color. Faint colors may be seen better by looking down the tube. Some variations in the amount of cyanide, zinc dust or lead nitrate may be necessary with different solutions. The lead should be kept down as far as possible, using the minimum that will give a precipitate that settles rapidly, as this will require a minimum of nitric acid. Too much nitric acid may interfere with the production of the final color. Mercury also gives a dark coloration, and somewhat affects the color given by gold.

The extension of flotation to the treatment of disseminated copper ore is indicated in the report that the Nevada Consolidated Copper Co. will install a flotation unit for experimental purposes.

Progress at the new mill of the Alaska Gold Mines Co. is said to be satisfactory. The steel for the coarse crushing unit is practically erected, and the roll and concentrating sections are under way. Concrete for foundations in the roll plant has been poured at the rate of about 300 yd. per day.

The smelter smoke nuisance is not confined to the western states. Residents of Staten Island, N. Y., have succeeded in having indictments returned against a number of New Jersey smelting and refining companies, charging them with maintaining a nuisance detrimental to public health and property. The court and counsel for the defendant companies have indicated their desire to effect an amicable settlement.

Refining of platinum is performed in the San Francisco branch of the Bureau of Mines by boiling the metal, about 75 grams at a time, in a cupel heated by an oxy-acetylene flame. The metal thus refined is softer and more pliable than before the treatment.

Three-Metal Bronzes

BY ALLMAND M. BLOW

A great many of the commercial bronzes and the trade-named bronzes, which are really brasses, contain added metals besides copper and tin, either for the beneficial properties derived from such additions, or because impurities are present which do not seriously affect the alloy under working conditions. The last is not true for impurities such as sulphur and oxygen; whereas iron, frequently present in small quantities in spelter, is a beneficial impurity, and special means are often taken to alloy it perfectly with bronze. Among the principal metals added to bronze are lead, zinc, phosphorus, manganese and aluminium, and as such they comprise a group of special bronzes or three-metal systems, in distinction to the regular copper-tin alloy. In addition, a number of commercial alloys are sold as bronze, when they are really of a zinc base. In general, the higher price demanded for bronze and the excess price of tin over zinc to the manufacturer, is the cause of this. Before going into the effect of other metals on bronze a brief outline of the true copper-tin alloys will suffice.

Copper-Tin Alloys

Fig. 1 is the familiar copper-tin temperature-composition diagram as originally worked out by Heycock and Neville. Other investigators claim a few slight variations from this curve, but for the most part it is generally accepted. The portion *B C c d* is the disputed area, wherein additional changes are claimed to take place.

At any temperature and composition above the line *A B C D E F* copper and tin form a homogeneous liquid. A decrease of temperature to this line (liquidus) immediately starts the freezing out of certain constituents of that liquid, depending on the composition. The line *A b c d g h i j F* (solidus) likewise indicates the completion of the solidification. An alloy of a certain composition, at a temperature above the liquidus, will, on cooling to room temperature, go through certain reactions at the horizontal and curved lines, and contain such constituents as are included in the vertical lines.

The series contains two solid solutions, alpha and beta, and three compounds Cu_3Sn , Cu_2Sn and Cu_5Sn . The former are true solid solutions of tin in copper as they are homogeneous in structure throughout. The eutectic, or alloy of lowest freezing point, is at 1 per cent copper. A change in the solid state, or eutectoid point, occurs at about 25 per cent tin. The alloys containing high copper are of the greatest importance and as the percentage of tin increases the alloy becomes brittle and therefore of less use. However, at about 80 per cent tin the alloy is practical but contains too much tin to compete profitably with other alloys of equal properties. The usual alloy does not contain more than 25 per cent tin and up to this composition there are two general classes, i.e., tin from 0 per cent to 12 per cent, sheet bronze and gunmetal; and tin from 10 per cent to 25 per cent, bell-metal. Considering the diagram from left to right, solid solution alpha is obtained up to 10 per cent tin. From this point to 25 per cent tin an alloy on cooling will freeze out alpha when reaching the line *A B*. The liquid remaining will follow this line down to *B* where at 795 deg. C. there will be alpha of 10 per cent tin and the liquid of 25 per cent tin. A reaction then occurs whereby solid solution alpha + liquid *B* = solid solution beta. Beta will form as long as both of these are present and the alloy will finally solidify completely when one or the other is used up. Decreasing amounts of tin from 25 per cent will cause the liquid to be used up first, leaving more alpha in proportion to the decrease toward 10 per

cent. In any case, the alloy is solid at 795 deg. C., and then further lowering of the temperature caused the beta formed (22 per cent tin) to pass down the line *c e*, which is accompanied by the formation of a little more alpha until the eutectoid point at 500 deg. C. is reached. Here a further change takes place by the breaking down of beta into a mechanical mixture of alpha and Cu_3Sn , or the eutectoid. On the other side of this point, beta will throw down one or both of two compounds instead of alpha. Above 32 per cent tin, Cu_2Sn will form first from the beta and at 580 deg. C. a reaction produces, Cu_5Sn . From 25 per cent up to 32 per cent tin the latter will form first, and as before, at 500 deg. C. the eutectoid of alpha and Cu_3Sn will cease the changes.

The rate of freezing and cooling will affect these compounds and solutions to a great extent, both in their composition and structure. Alpha, according to the diagram contains nominally 10 per cent tin in solid solution. Long annealing will increase this to 12 per cent without the eutectoid appearing, whereas in the practice of casting, the eutectoid may be seen when only 6 per cent tin is present. The eutectoid contains Cu_3Sn which is hard and brittle and is therefore not generally desirable. Gunmetal, according to the previous classification is then all alpha. For a combination of strength, elasticity, toughness and ability to withstand shock, alpha is the most desirable. Other metals increase these properties; but a true bronze containing 9 per cent tin has the following values:

| | |
|------------------------|------------------------|
| Tensile strength | 32,000 lb. per sq. in. |
| Elastic limit | 13,000 " " " |
| Elongation in 4 inches | 14 per cent. |

Since no transformation points are passed in the annealing of alpha bronzes, they are practically uninfluenced by heat treatment. But as the tin content is increased more of the eutectoid is present and the alloy comes into the class of bell-metals, which are hard or soft, and will have different tones depending on the amount of Cu_3Sn content of the eutectoid. These alloys above 12 per cent tin are very susceptible to heat treatment. By quenching from above 500 deg. C. (formation of the eutectoid) the eutectoid is partially prevented from forming and the alloy is more malleable by containing beta.

Tin up to 32 per cent produces an increasing amount of Cu_3Sn , until just at 31.8 per cent pure Cu_3Sn is obtained. This alloy is given the name of Speculum metal because of the high polish it will take, thus adapting it to minor uses. It is very brittle. A mixture of Cu_3Sn and Cu_5Sn is obtained in the range 31.8 to 38% tin.

The solid solution beta breaks up into the eutectoid when slowly cooled so that equilibrium is established. However, in this range of composition the alloys are much influenced by heat treatment and quenching. The microstructure of an alloy quenched from within this range shows that some of the beta is retained in the final metal. By treating in this way, the most beta is retained in alloys from 22 per cent to 25 per cent tin, and consequently the final state will consist of beta, alpha and the eutectoid in varying amounts. Beta is desirable to increase the tensile strength and for that property only it is more suitable than alpha. An alloy containing 22 per cent tin, treated so as to get the most beta, will have a tensile strength of about 40,000 lb. per sq. in. The other values are low. Alpha will increase the ductility at the expense of tensile strength, hence a balance must be obtained between the two.

Above 32 per cent tin brings the series into the range of Cu_2Sn and Cu_5Sn , alloys containing which have little strength and seldom enter into the three-metal bronzes. At 80 per cent tin the useful properties are somewhat regained, rising from around 2000 lb. ten-

tile strength in the middle of the series, to about 7000 lb., when the strength again decreases.*

The Effect of Lead on Bronze

In most cases the addition of one metal to another gives a lower mutual freezing point, hence it follows that lead should have a decreasing effect on the temperature changes of the copper-tin diagram. This is found to be the case; and because of the soft nature of the lead and its much lower freezing point than that of a bronze of 10 per cent tin, the resulting alloy is softer, and, on account of these properties the name of "plastic bronze" is applied to this type. By discussing the equilibrium diagrams first, a clearer understanding of the physical properties may be obtained when the lead varies from maximum to minimum.

Fig. 2 shows the temperature-composition diagram of copper and lead. These two metals belong to the class of alloys that are incompletely soluble in each

an eutectic point at 62 per cent tin and 182 deg. C. On either side of this point, as the case may be, lead or tin will freeze out first until the liquid is enriched to the eutectic composition; then the alloy will all go solid by the precipitation of this mechanical mixture of lead and tin, the eutectic. Under favorable conditions of cooling, a small percentage of lead (say 3 per cent) may be held in solid solution by the tin; and likewise for tin in lead.

By combining these three diagrams, Fig. 4, the ternary is obtained in which temperature is normal to the plane of the paper and the lines within the triangle represent projections to the horizontal of the intersections of the surfaces of the solid figure. Since each corner of the triangle represents 100 per cent of one of the metals, a surface connecting adjacent sides at this corner and projected on to the horizontal as an enclosed area, will include the first substance to freeze out when all three metals are present, should the composition of the alloy happen to lie within this enclosed area. Thus the area *Cu GB* shows that with copper and tin, alpha forms first; with copper and lead, copper is the first precipitant; but instead of having the two the excess copper produces more alpha, so the result is alpha alone in this area. Beyond the solubility of tin in copper to form alpha, other compounds are introduced represented by other areas, and the intersections mark the change from one to another. The arrows indicate the slope of the projected surface intersections.

A few of the internal change points of this ternary diagram, as to temperature and composition, have been determined accurately by early investigators, notably the direction and slope of the line *GB*; but as to the other parts of the figure there seems to be a lack of authoritative information. Consequently this figure is presented in the way of predicting the results we hope to obtain later, and, while the lines within the diagram will not, with our present knowledge, indicate accurately the limits in composition of the constituents, they will serve to enclose an area in which certain compounds and solutions exist.

Thirty per cent of lead in bronze is about the practical limit. Hence the lower left corner of the ternary is the most important. In the area *Cu GB*, alpha will freeze first. The line *GB* shows that as the temperature falls and this area is intersected, alpha is thrown out and the liquid follows the surface down on a line through the corner, then the saturation point (along *GB*) of the first liquid (originally 65 per cent copper) is reached sooner and at a lower temperature with increasing amounts of tin. This fact is to be noted later in connection with segregation, but since the copper-rich liquid still freezes out alpha to form more of the second liquid *H* (which gives alpha also), there is no interference with the formation of alpha, so it is likewise the first solid to form in the entire area, *Cu Pb B*. The line *HJ* is similar to *GB*, marking the beginning of freezing of alpha from the lead-rich liquid. Final freezing takes place at 326 deg. C. when the lead separates out. The alpha formed by the above reactions follows the changes as described before. First will occur the reaction to form beta, then at 500 deg. C. it will give place to alpha and the eutectoid. The line *B Pb* represents this beta-forming reaction.

When there is sufficient tin in the alloy this line will be met on cooling and the liquid will follow it in the direction of the arrow, forming beta. Of course, the composition determines whether the alloy will all go solid before this line is reached; but as the tin increases above 10 per cent the conditions are more favorable and then the beta reaction continues along *Pb B* until no more liquid remains. In the area *G H J B*, at an elevated temperature, are the two liquids;

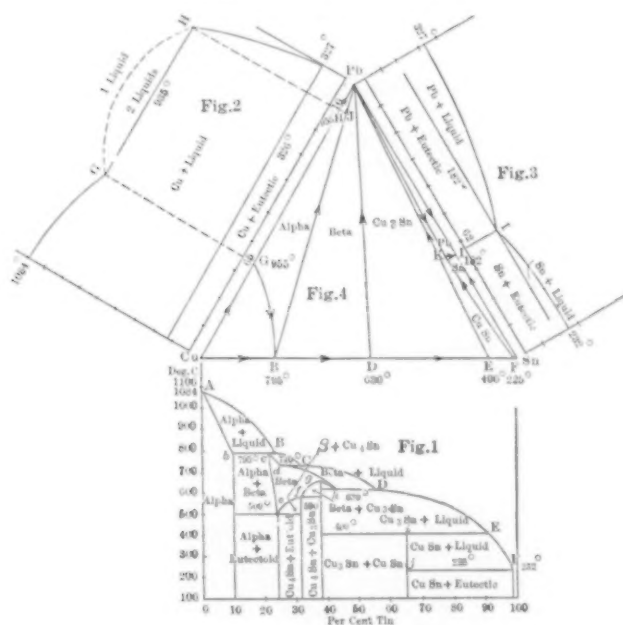


FIG. 1, 2, 3 AND 4—TEMPERATURE-COMPOSITION DIAGRAMS FOR COPPER-TIN, COPPER-LEAD, LEAD-TIN AND TERNARY

other in the liquid state and completely insoluble in the solid state. The curve given is generally accepted as correct by the many investigators of this alloy. An eutectic point is at practically pure lead (99.94 per cent) at 326 deg. C. Within the dotted half-circle there are two liquids corresponding to 10 per cent and 65 per cent copper; without it, there is a single homogeneous liquid. A copper-rich alloy will freeze out copper to start with when the temperature is lowered so as to strike the line *Cu G*. The liquid is robbed of its copper until at 950 deg. C. it contains 65 per cent at the point *G*. Then further freezing out of copper causes the formation of the second liquid containing only 10 per cent, and the temperature remains constant until no more of the first liquid remains. One liquid is formed at the expense of the other and copper is precipitated. When the reaction has continued to the point *H* then, and only then, will the temperature fall by freezing out more copper from the 10 per cent liquid, the final solidification being at 326 deg. C.

Lead and tin (Fig. 3) form a very simple curve with

*The strength values given throughout this paper cannot be used for rigid comparison even with alloys of similar composition. Chilled and cast test bars of the same metal, and pieces of the same bar will often give varying results. Standard testing methods are still being discussed.

mentioned before and it is safe to assume that the copper-rich liquid predominates over the other in furnishing beta to a bronze around 25 per cent lead, if only because it is the first liquid to form. The reaction $\alpha + \text{liquid } G = \text{beta}$ will continue until there is no more alpha or liquid, but the latter will evidently be exhausted first as it is being consumed by the formation of the second liquid, and besides, more alpha is being furnished. Consequently as a source of supply the liquid *G*, even being rich in copper, does not allow the beta reaction to progress very far. The other liquid, *H*, having a high lead content, has a depressing effect on the reaction line, hence its slope is toward *Pb* as the liquid is enriched in lead, and the beta precipitated from it is thrown out at a constantly falling temperature. The beta furnished by this liquid is little for the ordinary percentage of lead in bronze; but in any case beta freezes out as the liquids follow the line *B J*. When the liquid reaches *J* a rapid reduction in temperature takes place with a small change in composition of the liquid. Finally at *Pb*, if the liquid has not all been used up by the above reactions, the alloy becomes solid at 326 deg. C.

B Pb C encloses an area in which beta is the first solid to form should the composition of the alloy lie in this area. By precipitating this solid solution the liquid is changed in composition until it reaches the line *D Pb*, which represents a similar reaction to that at *B* whereby $\text{beta} + \text{liquid} = \text{Cu}_3\text{Sn}$. This reaction continues as the liquid follows *D Pb* as long as both constituents of the reaction are present. If beta is used up before *Pb* is reached the liquid will freeze further as in the next area. As before, at 326 deg. C., the freezing of lead will complete the solidification. Similarly the next line, *E Pb*, denotes the formation of Cu_3Sn from the liquid and Cu_3Sn , the latter being the first to freeze in the area *D Pb E*. Again, *E Pb F* gives Cu_3Sn as the first solid to be thrown out of the liquid. Should the composition of the alloy be such that in cooling the liquid reaches *FK*, there will be a reaction between the Cu_3Sn and the liquid to form tin, the composition of the liquid passing down the line to *K*. When the liquid is exhausted the alloy goes solid, but should it hold out until *K* is reached a further reaction takes place: $\text{Cu}_3\text{Sn} + \text{liquid } K = \text{solid lead} + \text{solid tin}$, giving the ordinary eutectic of lead and tin. Solidification continues down to *I* as long as the liquid supplies the reaction. In a like manner *Pb K* represents the simultaneous freezing of Cu_3Sn and lead (instead of tin) and at *K* the above reaction occurs again with the liquid and Cu_3Sn . In the area *Pb I K* lead freezes first, in *FKI Cu* tin, and along *K I* the eutectic of lead and tin. The point *I* is the binary eutectic of lead and tin and also the eutectic of the system.

The effect of lead on the physical properties and microstructure of bronze is for the most part simple. At times a fourth metal is added to make the desirable properties more pronounced; this addition and the rate of cooling are factors very influential on the structure of the alloy, so there is usually a departure from the normal constituents shown by the diagram. Lead and copper form no compounds or eutectic (the 0.06 per cent Cu eutectic not considered) consequently no compounds or solutions of these two metals are found in the alloy when the cooling is slow. Under normal conditions the only difference between a high and a low lead bronze is the amount of lead distributed throughout the mass after solidification, the lead merely retarding the final freezing to 326 deg. C. and giving the alloy the property of plasticity. Microscopically plastic bronze shows black patches of lead set in the ground mass of bronze (alpha and eutectoid), and in this respect it differs from most anti-friction alloys. The

ground mass is harder in this alloy than the included particles. The application of this type of bronze is almost exclusively as a bearing, and for heavy work it is widely used.

The experiments conducted by the Pennsylvania Railroad are responsible to a great extent for our knowledge of the behavior of lead bronze under working conditions. For a long time the limit of lead was 15 per cent; more than this caused difficulties in the preparation of the alloy. This difficulty was segregation and the ternary diagram easily explains the reason. First, consider copper and lead alone. With lead from 35 per cent to 90 per cent, there are two liquids from which the crystallization starts, and these being of a different specific gravity there is a separation or segregation in the liquid state. Then there is an unequal distribution of the solids crystallized from these liquids. On the other hand with lead up to 35 per cent there is only one liquid from which the freezing starts and this trouble is reduced immensely as regards this particular cause of segregation. While an alloy with the percentage of lead as in the last case was more productive of good results than with more lead, still a good casting was difficult to produce because of the too rapid cooling. Then it was found that by introducing tin a more homogeneous product was obtained and this is explained by alpha taking the place of copper alone. However, in the early practice the amount introduced was small because of the further observation that the lower the tin (consistent with homogeneity) the more lead could be added to the copper. Here again the diagram furnishes an explanation by the more recent experimental determination that the 35 per cent saturation point decreases with the addition of tin, so that as this metal is added the outside limits of the two liquids are extended and segregation is more likely to take place. So far, the early difficulties with this alloy are explained by the diagram, but by refinements in the mixing, casting and heat treatment, the old limit of lead, beyond which poor results were obtained, has been increased so that 30 per cent is not uncommon now. By the mechanical manipulation of alloy making, solutions and compounds are often made to change their limits; but since a diagram cannot be made to cover all the various practices, one must be adopted that represents the changes under normal conditions and when equilibrium is established.

Segregation has been the cause of the failure of many alloys. But now that recent knowledge shows the cause for this the trouble has been successfully overcome, not so much by varying the proportions of the constituents, but by the proper handling of the alloy while being compounded, and having the best properties to start with. By learning from curves and thermal diagrams what will be produced for a given mixture, it is easier to foresee trouble and avoid it.

Among the addition metals found to aid in preventing this trouble, the principal ones are nickel, sulphur and phosphorus. One per cent of nickel is said to improve a lead bronze so that with unskillful handling good results and little sweating are obtained with lead at 30 per cent. Copper and nickel are quite soluble in each other in the solid state, so nickel has the effect of producing more alpha solid solution in addition to the regular copper-tin alpha. Also under certain conditions it might be all dissolved in the copper-tin alpha. By a somewhat different method sulphur (added in the form of galena), also decreases the probability of segregation. Cu_2S is formed and the dotted half-circle enclosing the two liquids is flattened toward *GH*. The alloy "Allen Metal" contains sulphur as Cu_2S . Phosphorus affects the alloy in a different way. This metal is very often associated with lead bronze and alone

with copper constitutes another class of bronze that will be dealt with later.

Phosphor-lead bronze shows, in addition to the other constituents, varying amounts of the hard compound Cu_3P , which in a measure offsets the softer patches of lead. It is not often desirable to counteract the softening effect of the lead, because a soft bearing metal that will take the wear is better than a hard mixture that wears the journal. But phosphorus causes a good casting to be made from the alloy and therein lies its principal advantage. For a number of years the standard bearing-metal used by the Pennsylvania Railroad for its car journals was of this composition: 79.7 per cent copper, 10 per cent tin, 9.5 per cent lead and 0.8 per cent phosphorus. The more recent tests caused the adoption of a metal higher in lead and lower in tin on which the comparative wear was some 13 per cent slower than the first standard phosphor-bronze. This metal has the composition: 76.8 per cent copper, 8 per cent tin, 15 per cent lead and 0.2 per cent phosphorus and shows about 24,000 lb. per sq. in. tensile strength as against 30,000 lb. for the old standard. Another discovery is the successful substitution of arsenic for phosphorus. The tendency since then has been to increase the lead more and more and now the alloy commonly sold under the name of "plastic bronze" contains 30 per cent lead, 65 per cent copper and 5 per cent tin. This alloy is very satisfactory, and stands up well even in heavy locomotive bearings and for cars of the largest capacity. A compressive strength of 15,000 lb. per sq. in. is claimed for it, but it has excellent anti-friction qualities.

Other than for bearing metals, lead affects bronze by giving it superior machining properties, and also the appearance of aging or so-called "Patina," a dull bronze polish appreciated in bronze statuary.

The Effect of Zinc on Bronze

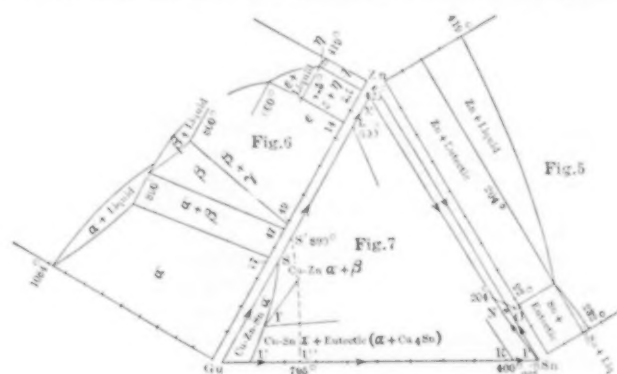
This phase of the subject could just as well be termed, "The Effect of Tin on Brass" and if so considered together the entire field of brass and bronze is included. Whereas others have written books on the history, physical properties and preparation of these two alloys, the ordinary metallurgist is not fully enlightened regarding their constitution. The microscope establishes at once the fact, the explanation and the proof of the constituents of brass and bronze, and the once dark secrets of alloy making are now being illuminated by the modern scientific searchlight. It is the purpose of the writer to illuminate a few of these dark points; but more important to the chemist and the average metallurgist is a brief description of the most prominent characteristics of brass and bronze, their appearance and the reason therefore. As mentioned before the subject is very extensive, and to deliver this kind of knowledge it would be best to follow the first heading of this division and further limit the discussion to high-tin bronze, with a few words about the other end of the series. Not that other compositions are not important but only bronze is under consideration here and the scope of this paper does not allow further elaboration.

Copper and tin is the base of the ternary (Fig. 7) as before. Zinc and tin (Fig. 5) form a very simple series without compounds and solid solutions. An eutectic point is at 8 per cent zinc and 204 deg. C.; to the left the solid alloy shows zinc and the eutectic, while to the right, tin and the eutectic are present. On the other hand zinc and copper (Fig. 6) give a brass consisting of a number of solid solutions depending on the composition. The series is more complicated than copper and tin, and there is less agreement among allo-graphists as to the points of temperature and composition change, especially in the middle of the diagram.

Consequently the two ends will be dealt with here; besides they are more important than the middle values. Three solid solutions are worthy of special notice: epsilon, of 14 per cent copper; beta, of 2.5 per cent copper, and alpha, of 37 per cent zinc.

First, a few of the principal constituents of this class of bronze.

The point of lowest temperature of the ternary is the eutectic of zinc and tin at 204 deg. C. The area $L M N$ includes the solid solution epsilon (14 per cent copper) as the first solid to freeze, while the liquid is enriched until the line $M N$ is reached. This is followed while the liquid plus epsilon gives solid beta, which with copper and zinc alone occurs at 425 deg. C (Fig. 6) and it is similar to the beta reaction in bronze. Should the liquid be exhausted before N is reached the alloy will go solid upon exhaustion, but if epsilon is used before the liquid, the liquid freezes further as in the next area $M Z n O N$. In the event both are present to allow the liquid to reach N , there occurs the reaction epsilon



FIGS. 5, 6 AND 7—TEMPERATURE-COMPOSITION DIAGRAMS FOR ZINC-TIN, ZINC-COPPER AND TERNARY

plus liquid N equals solid beta plus solid tin, which continues until final solidification.

In the area $M Z n O N$, beta solid solution freezes first until the liquid reaches $N O$ when beta and tin are precipitated side by side, similar to the ordinary eutectic. Finally the solidification is completed at O , the binary eutectic point.

CuSn freezes first in the area $R N P$ and when the liquid reaches $N P$ there will be a simultaneous freezing of CuSn and tin. At N , should the liquid reach there, will occur the same reaction as above with CuSn in place of epsilon.

The area $N O S n P$ yields tin as the first crystals and as before along $N O$ the beta-tin eutectic completes the freezing.

As an example of a commercial alloy in the above areas one of the Lumen Bearing Company alloys of about 85 per cent zinc, 10 per cent tin and 5 per cent copper, is illustrative. This solid alloy shows dendrites of epsilon, the first to freeze, surrounded by envelopes of beta, which formed along the line $M N$, and small streaks of beta plus tin in the ground mass produced by the reaction at N .

Again Parsons' white brass, which may be represented by the composition, 30 per cent zinc, 65 per cent tin and 5 per cent copper, shows beta and epsilon as before, but a much greater proportion of the eta-tin eutectic ground mass, as the excess liquid allowed the reaction at N , and the formation of the eutectic along $N O$, to progress much further. The eutectic being softer than the other constituents, the alloy containing the most, as in the last alloy, will have a softer ground mass and less hard dendrites. Here is the difference in structure between this type of bronze and lead bronze. When the copper content increases sev-

eral per cent above 8 per cent in a high-tin bronze, and 14 per cent in a high-zinc bronze, Cu_3Sn and epsilon with little beta are introduced respectively. The former is detrimental to a good bronze and it is usually formed unwillingly by being included in the kernels of Cu_3Sn and thereby stopping the action which should continue (and does on slow cooling) until all the Cu_3Sn has given place to CuSn .

Now in the general run of this type of bronze the copper jumps to above 80 per cent when the zinc is low. The intermediate percentages between 8 per cent and 80 per cent are seldom encountered for the reason that the compounds found in this range are mostly brittle. A great many alloys have their compositions in the area $S U Cu$. From Fig. 6 it is seen that the copper-zinc solid solution alpha is present up to 37 per cent zinc, and from Fig. 1 the copper-tin alpha up to 10 per cent tin. Therefore, $S U Cu$ encloses an area in which there is present the combined solid solution, copper-zinc-tin alpha; that is, in the solid state, as copper-tin alpha is precipitated from the liquid state up to 25 per cent tin, but upon cooling gives the eutectoid, so that to give alpha only, the limit is 10 per cent (normally). The same is true for copper-zinc alpha which freezes first up to about 45 per cent zinc, but in the solid state copper-zinc beta may be introduced if the zinc is much above 37 per cent. The second line $S' U'$ shows the limits of alpha when freezing from the liquid. The point T may be taken as the dividing point between brass and bronze. On the zinc side, copper-zinc beta throws the alloy into the brasses. On the tin side, the presence of the eutectoid determines the alloy as bronze. The area between encloses a mixture of the two.

Consider, for example, an alloy of 88 per cent copper, 10 per cent tin and 2 per cent zinc. Normally this composition is just on the line of separation beyond which the eutectoid appears. The zinc is all in the solid solution alpha because it is a value far below the saturation point of zinc in copper. Slow cooling produces homogeneous grains of alpha, but if the reaction, alpha plus liquid equals beta, is not allowed to be complete the grains are surrounded by some eutectoid formed from beta, and the two will appear as concentric circles. Of course, this alloy is practically identical in structure to ordinary bronze; the zinc changing alpha only slightly. Also, the physical properties are not altered much, a slight gain in tensile strength and ductility being apparent as a result of the zinc.

With more zinc another class of alloy comes under consideration. Zinc around 40 per cent with little tin gives the structure of Muntz metal, which is so characteristic that other alloys of similar appearance are classed in the Muntz metal group. Tobin bronze, manganese bronze and a number of heavy bearing metals come under this classification, and, as far as their zinc content is concerned, they are strictly brasses and not bronzes. Tobin bronze, for example, containing about 59 per cent copper, 38 per cent zinc, 2 per cent tin and a small amount of lead, is in the solid a mixture of the ternary alpha and copper-zinc beta, while all the tin is in the solid solution alpha. A reaction at about 890 deg. C. produces the beta from the alpha and liquid.

From these examples it can be understood that in a true bronze or a true brass the small amounts of zinc or of tin remain in the solid solution alpha, and the presence of the eutectoid on the one hand, and beta on the other, determines the bronze or brass nature of the alloy. These amounts of zinc in bronze or tin in brass do not affect the appearance of the solid alloy—it still remains bronze or brass, but the physical properties change accordingly.

One of the principal effects of zinc on bronze is the greater ease of cold rolling and forging. And its advantages in sea water are well known, especially of Tobin bronze. This alloy has a tensile strength in the neighborhood of 76,000 lb. per sq. in. when rolled, but greater ductility is obtained with a little less zinc. The cast alloy may have a value somewhat less than this, while cold rolling increases it slightly. It must be said that this high tensile strength is obtained at the expense of some of the other desirable properties, ductility for instance. Annealing and quenching play an important part in this connection. If an alloy of, say, 30 per cent zinc is heated to about 700 deg. C. and quenched in water, some beta is retained which would otherwise be absent. Again, a composition in the alpha plus beta range, by the same treatment, is made to consist mostly of beta. If so much tin is present in a bronze that it is ordinarily brittle, quenching from above 600 deg. C. gives copper-tin beta and the result is a workable alloy. The main field of the alloys in the copper corner of the ternary, is strength and salt water uses; those along the tin-zinc side come more strictly in the class of bearing metals or "white metals," particularly the zinc corner. They are harder than the lead-tin-antimony-bearing metals and more adapted to heavy loads.

The Effect of Phosphorus on Bronze

Phosphorus is added to bronze for either, or both, of two reasons:

1. As a deoxidizer; and, therefore, as it passes into the slag no phosphorus is found in the alloy on analysis.
2. For its beneficial effects; and then it is either, (a) all in solid solution, or, (b) in the form of the compound Cu_3P .

Normally phosphor-bronze contains a large percentage of copper and a very small proportion of phosphorus. Part of the copper-phosphorus diagram is given in Fig. 8. A definite, very hard compound, Cu_3P , is obtained with 14.1 per cent phosphorus which with copper forms an eutectic at 700 deg. C. and 8.25 per cent phosphorus. These figures are due to the investigations of Heyn and Bauer. Also copper is capable of holding phosphorus in solid solutions up to 1 per cent on long annealing. Fig. 9 shows the copper corner of the ternary diagram adapted from Hudson and Law's researches but with changes which, while contrary to their theory, seem to be more or less self evident.

Consider an alloy in the area $Cu V X$; alpha, holding a little phosphorus in solution, freezes first until the line WX is reached, then beta freezes by the familiar reaction as in bronze until W is reached. Here, should liquid still remain, occurs the reaction, alpha plus liquid W equals beta plus Cu_3P , until the alloy finally becomes solid. Then beta gives place to the eutectoid as usual below 500 deg. C. The final structure then is alpha dendrites surrounded by, and in a ground mass of, an eutectic-like structure of Cu_3P and the eutectoid (Cu_3Sn and alpha). The point W (81 per cent copper, 14.2 per cent tin, 4.8 per cent phosphorus, at 620 deg. C.) according to Hudson and Law is the ternary eutectic of the system, but as William Campbell puts it, it could be more truly called a reaction point whereby the liquid with alpha form beta, and the beta in turn forming the eutectic with Cu_3P and causing final solidification. Besides upon further cooling, beta breaks up into the eutectoid and the final alloy (unless quenched) contains no beta. It might be said that the high-phosphorus alloys contain the compound Cu_3P as a pseudo-eutectic mixed with the eutectoid of alpha and Cu_3Sn ; but with little phosphorus present it is dissolved in the alpha. The line VW represents the solidification of alpha and Cu_3P side by side until W is reached when the above

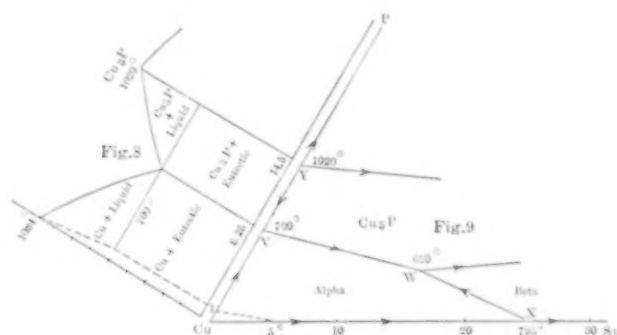
reaction takes place again. In the area VWY , Cu_3P crystallizes out first and along VW the changes are the same as explained before. Small amounts of phosphorus seem to lower the solubility of tin in copper from 10 per cent to about 5 per cent, even when annealed.

Then if the tin is present much more in amount than this, Cu_3Sn is introduced through the eutectoid, which, with the Cu_3P , gives two hard substances set in a softer alpha matrix. However, this matrix is harder than the lead-tin anti-friction alloys and therefore the plasticity of the former is less.

In general, the addition of phosphorus to bronze has the effect on the physical properties of greatly increasing the hardness and resistance to wear and for conditions requiring these qualities it surpasses all other alloys.

The other properties of the bronze, *i. e.*, the tensile strength, elastic limit and elongation, are impaired in proportion to the phosphorus added. Consequently, the phosphorus is kept low, relying more on its deoxidizing and cleaning powers to give to phosphor-bronze the good qualities it possesses.

The class of bronze in which both tin and phosphorus are low includes most of the commercial alloys and these show a certain degree of malleability and ductility. The upper limits in composition of these two metals for such properties may be placed at 8 per cent tin and 0.8 per cent phosphorus. Within these limits the phosphorus is held in solution in the solid alpha due to the



FIGS. 8 AND 9—TEMPERATURE-COMPOSITION DIAGRAM FOR COPPER-PHOSPHORUS AND PART OF TERNARY

long annealing which this alloy usually undergoes, and the result is a single homogeneous solid solution. Should this phosphorus limit be too great, so as to admit the possibility of forming Cu_3P , the tin hinders the action and further causes the compound to be distributed in finer patches throughout the mass. It is essential that if malleability is desired the hard substances Cu_3Sn and Cu_3P must be eliminated as far as possible. The commercial alloy frequently contains tin and phosphorus outside the above limits when hardness is not so detrimental to the particular use of the alloy. In fact, it has been found that other metals make up for the excess hardness produced by too much tin and phosphorus and by using such a metal to neutralize their hardening effects, the wide limits could be used to give other qualities and still give as a net result a comparatively soft alloy. Lead is nearly always present for anti-friction and softening purposes when the alloy is used in bearings. The purpose is to get the most suitable mixture of copper and tin to give strength, then harden and deoxidize it with phosphorus, and finally add lead to soften it somewhat and give the necessary anti-friction quality.

The alloy sold as phosphor-bronze has a tensile strength around 30,000 lb. per sq. in.

The Effect of Manganese, Aluminium and Iron on Bronze

In the first place, manganese bronze should be called manganese brass; and, again, a number of alloys sold under this name have no manganese whatever in them. Since manganese bronze is a name standing for strength, brass foundries turn out alloys and sell them under this name in order to market their product. Many of the reputable firms do this, which is admissible, as they have the strength to back their alloys, but it has been found that many manganese-bronzes have their strength only in their names.

In the composition of manganese bronze, aluminium is frequently of a greater percentage than manganese, so the modification could go still further—aluminium brass. Manganese and aluminium "bronze" are so closely related that it is difficult to discuss one without the other. It is true that the real aluminium bronze is still widely used for certain purposes and until the last few years it was a competitor of manganese bronze in the field of usefulness that the latter occupies now. It has been replaced, but in name only, by manganese bronze as the many desirable characters of this bronze are due largely to the aluminium it contains.

Manganese bronze dominates the field of combined strength and non-corrosive alloys. Monel metal is its only competitor—at a higher price. As a bearing metal it finds little application except under very light loads.

High-zinc brass gives unsatisfactory sand castings and therein lies the advantage and object of adding aluminium. Iron gives a high elastic limit to copper and zinc and hence the use of manganese as a carrier of the iron. Metallic iron melted with the alloy gives patches of ferrite which are hard and limit the machining of the metal. When introduced in the form of ferro-manganese this trouble is eliminated. P. M. Parsons was the first to determine the benefits of these added metals and although his patents have since expired, he introduced the alloy in England and later in the United States. His original mixtures have been changed very little.

The manganese bronze in use now has two compositions, one for sand casting and one for rolled sheets and forgings. The following will show about the average analysis and mixture:

| Sheets and Forgings | | Sand Casts | |
|---------------------|---------------------|------------|---------------------|
| Analysis | Founders' Mixture | Analysis | Founders' Mixture |
| Cu...60.1 | 60 lb. (Ingot) | 56.0 | 56 lb. (Ingot) |
| Zn...37.8 | 39 " (Pure Spelter) | 41.5 | 43 " (Pure Spelter) |
| Fe...1.3 | 2 " Steel Alloy | 1.2 | 2 " Steel Alloy |
| Sn...0.7 | | 0.7 | |
| Mn...0.1 | | 0.1 | |
| Al... .. | | 0.5 | 1/2 " (Ingot) |

Steel alloy: wrought iron 18 lb., ferromanganese (80% Fe, 40% Mn) 4 lb.; tin 10 lb.

The small proportion of manganese and the absence of aluminium in sheets is worthy of notice. When rolling and forging the alloy, better results are obtained with more copper and less zinc than is used in the sand casting mixture. Since both compositions give a Muntz metal structure, more copper will produce more alpha which is better adapted to being worked than beta. Aluminium is the beneficial element in the casting mixture, but since this alloy must be melted first in the proper order and cast into ingot bronze and then remelted for the final casting, it is eliminated in the rolling mixture which then only needs to be melted once.

Iron has an unlimited solubility in manganese and manganese has an unlimited solubility in copper; consequently these extra metals, together with tin and aluminium, are all in solution in the alpha. The copper and zinc percentages give the structure of Muntz metal so a diagram other than Fig. 6 is not necessary to explain the constitution of manganese bronze.

The reported strength values of this alloy vary considerably. The following, however, may be taken to represent averages from the above mixtures:

| | Cast Bars | Cold Rolled |
|-------------------------|------------------------|------------------------|
| Tensile strength..... | 70,000 lb. per sq. in. | 95,000 lb. per sq. in. |
| Elastic limit | 30,000 | 80,000 |
| Elongation in 6 in..... | 18 per cent | 12 per cent |

Another type of manganese bronze is used as a resistance alloy. It is white, due to 18 per cent manganese, and contains also about 67 per cent copper, 13 per cent zinc, 1 per cent aluminium and a little silicon. Its tensile strength is around 40,000 lb. per sq. in. for castings but its ductility is low. As to its resistance, it is claimed that 400 ohms per mil foot is a good average, while German silver for comparison, has about 180 ohms.

True aluminium bronze has many advantages that place it in a field of usefulness that cannot be invaded by manganese bronze.

The alloy has as its prominent characteristics a low specific gravity and the ability to make sound castings from bronze. But to offset these qualities, the casting shrinks considerably, has low ductility and possible brittleness. It seldom contains more than 11 per cent aluminium.

Part of the copper-aluminium equilibrium diagram is given in Fig. 10. It is somewhat similar to the left side of the copper tin curve, alpha holding 7.5 per cent of aluminium in solid solution, and the eutectoid point is at about 11.5 per cent aluminium. The best alloy contains alpha plus beta, obtained by quenching when the aluminium is between 7.5 per cent and 11.5 per cent. On either side of this range of composition, or when the eutectoid is present, the alloy is either weak or brittle. Eleven per cent of aluminium and 90 per cent copper is about the best composition, tests of which give around 80,000 lb. per sq. in. tensile strength. More aluminium causes excess brittleness, while less makes the alloy too weak, as for instance with only 1 per cent aluminium, 25,000 lb. is obtained. By introducing tin the alloy does not seem to be improved; i. e., 88 per cent copper, 6 per cent aluminium and 6 per cent tin gives nearly 65,000 lb. tensile strength, but greater ductility. The gas engine is responsible for the extensive use of an alloy high in aluminium. About the best of this class of alloy is 92 per cent aluminium and 8 per cent copper, to which some founders add a small amount of nickel. A tensile strength of 18,000 lb. per sq. in. is near the average value, but its principle advantage lies in its low specific gravity of about 2.8. It withstands repeated vibrations very well, much better than a similar alloy with the copper replaced by zinc, which has more strength.

Durango, Colo.

South Dakota made its record yield of metal in 1912, in which year the gross value of gold, silver, copper and lead was \$8,019,370. In 1913 the yield was valued at \$7,424,333 from 30 producing mines, including 10 placers. There was 1,895,445 tons of ore treated in the state, yielding an average recovery per ton of \$3.81 in gold and \$0.052 in silver. The Homestake mines and mills produced and treated 1,540,961 tons of ore, yielding bullion valued at \$6,186,652, or \$4.01 per ton.

Notes and Observations on Ore-Treatment at Cobalt, Ontario, Canada

BY H. C. PARMELEE

Ten years have elapsed since Cobalt made its first contribution to the silver production of the world. Within that period the shipment of silver ores and concentrates has increased in value from \$136,217 in 1904 to \$16,555,001 in 1913.¹ Shipment of bullion produced in the district increased from a value of \$501,815 in 1910 to \$5,895,449 in 1913. In the latter year Cobalt was credited with 14 per cent of the world's production of silver.

Mining at Cobalt always has been characterized by many spectacular features which have become a matter of common knowledge. The richness of the ore, the large masses of native silver, the deposits of cobalt and nickel minerals, and the development of an immense mining industry in a region supposed to be valuable only for agriculture and lumbering—these features have characterized Cobalt. Mining has indeed been unique, but no less striking have been the recent metallurgical advances, resulting in the accomplishment of things considered improbable, if not impossible. Nor is the end yet in sight, for there are indications that Cobalt is entering on a period of progress in metallurgy that will develop further novel processes and methods. Large problems still exist and good men are attacking them.

Present Situation and Future Prospects

Leaving out of consideration for the present the specific technical problems at Cobalt, the general economic situation is about this: In the early years of its history the district produced principally high-grade silver ore.

Other valuable minerals, chiefly of cobalt and nickel, existed in the ore, but their value was not comparable to that of the silver, and they received but little consideration, metallurgically speaking. Silver was the metal of chief value, and the ores were shipped and smelted for its recovery. Cobalt, nickel and arsenic were by-products of little economic value to the producer.

Low-grade ores also were developed, and these were enriched locally by ordinary methods of water concentration. The concentrates, too, were shipped from the district and smelted at other places in Canada and the United States. With the gradual and inevitable exhaustion of the high-grade ores, there was an increase in production and concentration of low-grade material. This tendency has been marked in the last few years; in 1912 the concentrating mills treated 390,473 tons of crude ore, and in 1913 they handled 531,548 tons. The prospect for the current year is that a still greater tonnage of low-grade ore will be enriched by concentration.

One of the most clearly defined elements of the situation, therefore, is that ore-dressing is a factor of increasing importance in the district. Lower grades of ore will be mined, old mine dumps will be treated, and every effort made to conserve the diminishing resources just as far as mechanical methods can be applied.

This means an increased production of the table concentrates, coincident with a decreased output of high-grade ore, and has an important bearing on the future of metallurgy in the district, as will be pointed out later.

¹Statistical data are quoted from the 1914 report of A. A. Cole, mining engineer to the Temiskaming & Northern Ontario Ry. Commission. This report is published annually and distributed by A. A. Cole, Cobalt, Ontario, Canada.

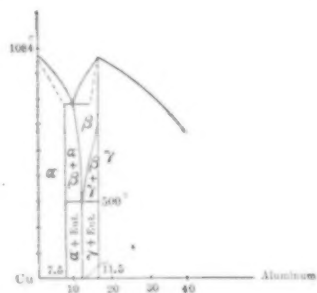


FIG. 10—PART OF COPPER-ALUMINIUM EQUILIBRIUM DIAGRAM

Local Production of Bullion and By-Products

Another feature of the metallurgical situation, which has been recognized by the progressive companies in the district, is the desirability of producing bullion at the mines instead of shipping ores and concentrates to smelters. The local output of a finished product, salable to mints or other consumers of silver, and the recovery of valuable by-products such as cobalt, nickel and arsenic, would be preferable to the shipment of raw material requiring further treatment, providing economic methods could be devised that would gain for the producer the profit which it may be assumed the smelter is making. Judging from the research now under way, it may be safely predicted that the production of silver bullion and by-products will increase, and shipments of raw material decrease considerably in the next few years. The general tendency toward the increased local treatment of ores by all methods—concentration, amalgamation and cyanidation—is shown by the following figures: for 1912, 455,517 tons; for 1913, 664,845 tons.

The reduction of ore to bullion and the recovery of some by-products has been an accomplished fact at Cobalt for several years past, but has been confined mainly to the treatment of high-grade ore and tailings from concentration. By far the greater proportion of the tonnage mined is concentrated, but the local reduction of table concentrates has not been as extensively practiced as it will be.

A scheme of amalgamation in strong cyanide solution is used for high-grade ore, while low-grade ore and tailings from concentration are treated by cyanidation only. The Nipissing company is successfully cyaniding ores similar in grade and character to those ordinarily concentrated at other mills; the Dominion Reduction Company is cyaniding concentrates and tailings separately; the Buffalo company is reducing jig and table concentrates with high-grade ore, and both the Buffalo and O'Brien are cyaniding slime tailings from concentrates. Details of these methods will be referred to later. The following tabulation shows the reduction methods used and materials treated.

| Company | By amalgamation and cyanidation | By cyanidation |
|-----------------------|---|---|
| Nipissing..... | High-grade ore and jig concentrates..... | Low-grade ore, Slime tailings from concentration. |
| Dominion Reduction... | Table concentrates.... | |
| Buffalo..... | High-grade ore, jig and table concentrates..... | Slime tailing from concentration. |
| O'Brien..... | | Slime tailings from concentration. |

A Complex-Ore Problem

The recovery of the valuable metals from the ores and concentrates of the Cobalt district presents a neat metallurgical problem, particularly with reference to table concentrates. Here we have truly a "complex-ore problem," although different in kind from what is usually understood by that term in the western United States. In order to appreciate the condition at Cobalt, consider the list of the principal minerals contained in the ores: native silver, sulphides of silver and nickel, arsenides of nickel and cobalt, arsenate of cobalt, sulpharsenides of iron and cobalt, antimonide of silver, sulphantimonite of silver, and some others. These minerals represent at least four metals of economic importance—silver, cobalt, nickel and arsenic—the recovery of which offers an opportunity for research and operative skill.

The reduction of table concentrates presents a different problem to that offered by high-grade ore. Comparatively little difficulty is experienced with the latter, as the silver is mainly in the native state and yields almost a complete recovery by amalgamation in cyanide solution. Table concentrates, however, differ in con-

taining a large proportion of the complex silver minerals and a smaller proportion of native silver. This mineral content is the main factor in the problem of reducing table concentrates and recovering therefrom the several metals of economic value.

Essentially two lines of attack are being made on this problem—by amalgamation and by cyanidation. Each is marked by a high consumption of the chemical employed and involves some scheme for its recovery.

Amalgamation will yield silver bullion and a residue containing principally cobalt, nickel and arsenic. There will be a comparatively heavy chemical consumption of mercury, due to the formation of mercury sulphide which remains with the residue. This necessitates a treatment of the residue for recovery of mercury. Such a process is in use at the Buffalo mill, and as soon as operating data are obtained we expect to be able to present details of the process and the metallurgical results.

Cyanidation of table concentrates, on the other hand, is being investigated by the Nipissing company. No details of results have been made public, but it can be surmised that a high chemical consumption of cyanide will ensue, and that some method for its regeneration and for the recovery of metals, other than silver, taken into solution, will be a part of the process. This research should add greatly to our knowledge of cyanide chemistry. It is expected that a process will be developed whereby high-grade ore concentrates can be treated by cyanidation only, eliminating amalgamation as now practiced by this company.

The outcome of these two different lines of research will be awaited with interest, for their success means much to the Cobalt district in the local production of bullion. The ultimate superiority of one method over the other must be determined by the metallurgical and economic results and the mechanical requirements, as shown in practical operation.

Chlorination has been proposed for the treatment of these ores, and some experimental work has been done by interested parties. Mr. John L. Malm, of Denver, made tests several years ago according to a method¹ which he has advocated for complex base-metal ores of the western United States; and in our last issue we recorded the details of a process² patented by Mr. Oscar Dyckerhoff, of Karlsruhe, Germany, specially applicable to Cobalt ores.

Retreatment of Sand Tailings from Concentration

The sand tailing dumps at some of the concentrators in Cobalt represent an asset worthy of conversion into money. The successful treatment of this material constitutes another metallurgical problem which is being investigated by several companies, and it is likely that within the next few years a large tonnage of this material will be treated by cyanidation.

The silver content of sand tailing will range from 4 to 8 oz. per ton. In the opinion of engineers thoroughly familiar with conditions and competent to judge, there is more 6 to 8 oz. tailing than is generally admitted. This is particularly true of earlier practice. Exceptions exist as in all such cases, and there are some sand dumps containing only 3 to 4 oz. silver per ton.

Under present conditions it is unlikely that any attempt will be made to retreat these lower-grade dumps, but enough work has been done on others to indicate the advisability of erecting the necessary grinding and cyaniding plants for their treatment. Dump sampling is not difficult, particularly where the tail-

¹This Journal, Feb., 1914, p. 128.

²This Journal, June, 1914, p. 412.

ings have been stacked and not run into the lakes. The piles are quite uniform in value, and accurate estimates can be made of their metal content.

Generally speaking these sand tailings, and very low-grade ores too, require fine grinding for the liberation of metal and mineral from the enclosing gangue. For this reason it is unlikely that further concentration would be an effective treatment. Screen analyses of sand dumps show a marked concentration of silver in the finest portion, say 200-mesh and finer, while the grades from 20 to 150-mesh, inclusive, will assay about the same as the whole sample. The following tabulation illustrates this condition, the figures representing a fair average of sand tailing containing about 6.5 oz. silver per ton.

| Mesh | Per Cent by Weight | Oz. Silver per Ton |
|-------|--------------------|--------------------|
| + 20 | 30 | 6.5 |
| + 40 | 35 | 6.2 |
| + 60 | 21 | 6.2 |
| + 80 | 7 | 5.8 |
| + 100 | 3 | 5.7 |
| + 150 | 2 | 6.3 |
| + 200 | 1 | 8.5 |
| - 200 | 1 | 28.6 |

Similar results, though with less striking concentration of metal in the finest portion, are obtainable from 3 and 4 oz. sand tailings.

The cyanidation of this material seems to offer no serious obstacles, when ground so that about 90 per cent. of the solids will pass a 200-mesh screen. By grinding in a tube mill in cyanide solution, and agitating the thickened pulp, an extraction of 90 per cent. is possible. A system of continuous counter-current decantation following agitation would complete a very simple and effective plant. The finely ground material is sandy and settles readily, so that from 5 to 7 sq. ft. of settling area per ton of dry slime is quite sufficient. The cost of cyanide would be from fifty to sixty cents per ton, and the total cost of treatment probably not more than \$1.75. Thus on material of \$3 to \$3.50 gross value, a fair profit could be realized, but 4-oz. tailings would not much more than pay for treatment.

Some interest is being taken also in the possibility of applying flotation to reground sand tailings, but only a few tests have been made. The point to be determined in this connection is whether the use of an intermediate concentrating process, followed by cyanidation or amalgamation of the concentrates, would yield a higher economic return than could be obtained by direct cyanidation as just outlined. The apparent advantage of flotation would be the greatly reduced volume of material to be treated in the final process, due to the rejection of the bulk of the gangue in the flotation process. This is a line of investigation that may be pushed further, as there are several types of flotation processes, one of which might be found specially applicable.

Cyanidation of Slime Tailings from Concentration

At two mills in the district, slime tailings from concentration are being cyanided. According to the report of Mr. A. A. Cole, previously mentioned, the Buffalo company in 1913 cyanided 11,744 tons of slime and produced 110,505 oz. silver; the O'Brien mill treated 39,663 tons of slime, producing therefrom 228,544 oz. silver. These facts suggest that the slime tailings now being wasted from concentrators are more valuable, ton for ton, than the sand, and that a recoverable asset is being neglected. Not only is it being neglected, but in some cases it is being put beyond the possibility of ultimate recovery by being discharged into lakes instead of being impounded.

There are several reasons why this preventable waste is to be deplored. In the first place a great deal of energy has been expended in grinding this slime, so that most of it is in a condition suitable for cyanidation, and would require but little more grinding. Again comparatively simple means are at hand for applying the cyanide process, and the additional cost of machinery, chemicals and labor would not be prohibitive in view of the possible recovery. If it is regarded as feasible to regrind and cyanide a 6 to 8 oz. sand tailing, it would seem possible to cyanide slime tailing of the same value which is already ground much finer, and requires practically only agitation for solution of the silver. Finally, this further treatment of slime offers a simple expedient for adding to the recovery effected by the concentrator, and should appeal to progressive metallurgists. Perhaps concentration by flotation might be applied to this material, and in that event the pulp would be ready for treatment after a preliminary thickening. Economically, however, it is likely that cyanidation, with its production of bullion, would be preferable to flotation and the recovery of concentrates requiring further reduction.

At the O'Brien mill the ore is first jigged in water and the jig tailings are then crushed in stamps in cyanide solution. Hardinge and tube mills are used as regrinders, and Deister tables make a further concentration of the reground pulp. Slime is finally separated by Dorr classifiers, thickened, agitated and filtered. The cyanide department at the Buffalo mill is an adjunct to the concentrator, and the scheme of treatment includes well known methods of thickening, agitating, filtering and precipitating.

Other companies in the district are now considering cyanidation as a logical extension of their work in concentration. Until methods are adopted which eliminate concentration altogether, this idea is an excellent one and worthy of wider use. The fullest credit is not reflected on the metallurgist as long as an economically recoverable asset is being wasted. In this problem, of course, are involved the life of the mine, the daily mill tonnage and the cost of additional plant.

The Story of Mining and Metallurgy

At the fiftieth anniversary of the School of Mines of Columbia University, on May 29, 1914, Mr. T. A. Rickard, as the official representative of the Royal School of Mines, London, made a brilliant address on the calling of the mining engineer and metallurgist.

Mr. Rickard spoke as follows:

"It is a common saying that agriculture and mining are the two basic industries. When man rose above the brutish individualism of his primordial state and began to develop the social instinct, he turned to the soil, in order to win food for his family. He paused in his migration, the soil held him; it gave root to his rudimentary community; it gave him the chance to enlarge his energies. His tracks became highways; his rivers, avenues of trade; and as his traffic expanded, so his imagination widened, until, out of the crudities of communal development grew the complexities of civilization.

"But the nomadic habit lingered; the spirit of the hunter survived in man; a wanderer and a wonderer he stood beneath the starry dome of the forest arch not knowing whether he were the guest or a captive in the domain of Nature. The hills beckoned; the seas called; the more venturesome left the tents of the tribe in search of material wherewith to fashion their implements. They sought iron for weapons, copper for tools, gold for ornament, and found them in various guise in the earth under their feet. They

became miners. To those who delved successfully came power. Throughout the ages the more energetic and adventurous broke from the plough and forsook the cattle in order to explore and to exploit. They brought the metals from which the artificers fashioned engines of power and machines of intelligence. They won the materials for a social structure that, based on stone and built in iron and copper, soared in many-storied tracery of steel to towers radiant with light and vibrant to the sky—towers so far above the common ground that man almost forgot his lowly origin and claimed kinship with the stars.

"The story of mineral exploration and racial migration is peculiarly the heritage of our people, the Anglo-Celts. It is the *motif* that runs through the drama of English and American history, more particularly during the last hundred years. Even in its barest outlines it serves to suggest that the miner is the pioneer of industry and the herald of empire.

"The first social organizations around the shores of the Mediterranean sent their prospectors to the hinterlands of Europe, Asia, and Africa. The gold of Ophir, the copper of Sinai, the silver of Laurium were part of the web and woof of those early civilizations. The mines of Iberia gave Hannibal the sinews of war against Rome, and the gold of Davia strengthened the resources of Rome under Trajan. But the greatest adventure was that of the Phoenicians who passed through the Pillars of Hercules into the western ocean in order to reach the far Cassitorides, the tin islands that in turn were to produce those Cornishmen to whom the world is one big mine. After Carthage and Rome, in turn, had been overthrown, the mining industries of the known world were disorganized. Desultory operations persisted in Hungary, Spain, and Saxony, but the Middle Ages to the miner were as dark below ground as above. Even the discovery of America, which marked the beginning of a new world movement, was not connected with a real advance in mineral exploitation, although associated with the winning of gold and silver. It is true, the wave of Spanish conquest broke over the American continent, penetrating the treasure-vaults of Mexico and Peru. But the Spaniard devastated, he did not develop. He gathered the harvest that the patient Indian has sown by the laborious toil of centuries. Cortez and Pizarro were filibusters, not explorers; they were pirates, not miners. The *conquistadores* were no pioneers of industry; behind them arose the smoke of ruin and the dust of destruction. Even the great sea-captains of Elizabeth were but the sequel to an epoch of spoliation. After them, and in their wake, across the sea, came the men who from Cornwall and Devon, from Saxony and the Harz, brought the technique of mining to the new world, applying it peacefully to the mineral development of Mexico, Peru, and Chile, all along the regions previously ravaged by European freebooters.

"But the great era of mineral exploration came with the discovery of gold in Australia and California. It was the prelude to a worldwide migration, an enormous expansion of trade, a tremendous advance in the arts of life, and the spread of industry to the waste places of the earth.

"The colour of energy began to tint the blank spaces on the map. The western half of the North American continent, all of Australia, the southern half of Africa, the northern half of Asia, were invaded, penetrated, and explored by those in search of gold, of other metals, and as each successive mineral discovery was made by the miner he called upon his fellows to come and take a hand in the good work. He was the scout far ahead of an army of develop-

ment. Trade follows the flag, it is true, but the flag follows the pick."

Mr. Rickard then told of the finding of gold in California by James W. Marshall on January 24, 1848, and of the sudden rush of the gold seekers to the Pacific Coast which is so well known in the history of California and which resulted in the production of \$81,294,700 in gold in 1851, giving details of the subsequent history of the industry. Among those who were first in those fields was E. H. Hargraves, an Australian, who was led by the analogy of geologic conditions to those in his own country to suspect the occurrence of gold there, and he returned to his home in New South Wales, where on April 3, 1851, he announced the discovery of gold in Australia. The rush to those gold fields was great and in 1853 the gold production there was \$54,882,000. The first diamond was found in South Africa, he said, in March, 1869. The history of the de Beers and Kimberly mines, the discoveries in other regions of the Rand and in the West African gold fields, the story of the Yukon and Klondike were next told. After speaking of the great work of prospectors in the development of the countries they visited, Mr. Rickard concluded by saying:

"After the prospector has come the mining engineer. The scout has gone in advance of the captain of industry. Those of you that have crossed the range in winter know how the loader breaks the trail by leaving footprints into which his followers tread, step by step, greatly to the safety and ease of their travel. That is what the mineral explorer has done for the mining engineer. That is what the mining engineer has done for those behind him. Some of you have been prospectors as well as engineers.

"Have you known the great white silence, not a snow-gemmed twig aquiver?

Have you broken trail on snowshoes; mushed your huskies up the river?

Have you marked the map's void spaces,

Felt the savage strength of brute in every thew?"

"Again I ask you to recall how you threaded the pathless forest on your way to examine a new mineral discovery. On the trees at intervals you have seen that the bark was chipped. The trail has been 'blazed' by the prospector, making it easy for you and others to follow. That is what the miner has done in a larger way for civilization. He has done it with geographical exuberance and equatorial amplitude. From 'the stark and sullen solitudes that sentinel the Pole' to the 'steaming stillness of the orchid-scented glade' in the Tropics, he has left his mark. You know that. No need for the prospector to complain to you, like Kipling's explorer:

"Well, I know who'll take the credit: all the clever chaps that followed—

Came a dozen men together—never knew my desert fears;

Tracked me by the camps I'd quitted, used the water holes I'd hollowed.

They'll go back and do the talking. They'll be called the Pioneers!"

"No; not by the men of the Columbia School of Mines, who have shared the prospectors' camp-fire, his blankets, his flapjacks, and his beans. You will give credit to whom it belongs. To the man with the faith of a child and the heart of a viking, to the man who has tramped and toiled until he heard "the mile-wide mutterings of unimagined rivers and beyond the nameless timber saw illimitable plains"; to the miner who has crossed the last range of all and lies in the only prospect-hole he could not dig; to the man who was the herald of empire and the pioneer of industry; to him who 'blazed the trail.'"

Is There a Complex-Ore Problem?

A Symposium on the Economics and Metallurgy of Mixed Base-Metal Sulphide Ores, Showing Present Status and Future Prospects of This Branch of Ore-Treatment

In our May and June issues we presented a number of replies received in answer to a set of questions propounded to leading metallurgists on the general subject of complex ores. The interest manifested in this inquiry has been all that could be expected, and indicates how widespread is the problem that is being attacked by many different methods and from different angles. We present below two additional replies that have been received, together with an editorial summary of the subject. For convenience in following the trend of the replies, the questions are here reproduced.

1. Is there a "complex-ore problem," and what, in your opinion, constitutes a "complex" ore?
2. Would such ores be amenable to present methods in the hands of skilled operators, or is there a need for new methods of treatment?
3. Do you believe there are many mines now idle which could produce a considerable tonnage of such ore if suitable methods of treatment were known?
4. What element or quality of such ores makes them refractory to present processes?
5. What methods or processes do you regard as probable solutions of the problem (mechanical, hydrometallurgical, electrometallurgical)?
6. To what extent would microscopical examination of such ores be of material assistance in suggesting proper methods of treatment?

F. L. Clerc.—The symposium to which we are invited for the discussion of the complex-ore problem has proved a social success. Let us all raise our glasses, whether they be eye-glasses, laboratory beakers, microscopes or telescopic lenses, to pledge ourselves to contribute to its solution; and in honor of the sentiment of cordial cooperation, drain the new life typified by the generous juice of the grape. My rôle must be mainly to second the motion, or endorse the opinion, of the last speaker. The subject has been covered so fully that any amendment I will suggest appears to me to be in the way of more fully expressing opinions already set forth. It is always of interest to know just how far such support and endorsement goes. This can be shown by a categorical answer to the questions submitted.

1.—Yes, there is a complex-ore problem, a general one: The maximum utilization of the valuable constituents of mixed mineral substances, and the discovery of uses for the other constituents. A complex ore is one in which the mineral or minerals containing one valuable constituent are intimately entangled with minerals containing other valuable or, at present, worthless constituents.

2.—All known mineral substances and compounds can be separated by laboratory methods. Metallurgical operations are modifications and extensions of laboratory manipulations. The question of profit involved may be answered Yes, if the skilled operators can live in the meantime.

3.—The lean-ore problem presents itself at every working mine, as attested by the mine dumps and piles of tailings and polluted streams. If these complex mixtures could be utilized, the tonnage from mines now working would be greatly increased. These mines could be opened and worked to better advantage, and the danger of losing the bonanzas by too contracted workings would be lessened. Doubtless there are many abandoned mines and discovered mineral deposits which can be profitably worked if the valuable constituents of the leaner complex ores can be made useful.

4.—The element which makes complex ores refrac-

tory to present processes is that one of least value commercially; that is, after deducting the cost of treatment. The quality which contributes to refractoriness is the intimate entanglement of minerals which require different treatment for the extraction of the valuable metals they contain.

5.—All of the methods or processes mentioned have their application to special cases of the general problem. They are being constantly improved in practice. All mechanical separations of ore containing one or more valuable constituents are stages of metallurgical treatment; even selective mining, crushing, hand-sorting and any method of separation or concentration. Transportation from mine to mill or smelter is included in the handling of ores, and a saving in any of these items renders increased amounts of complex ores amenable to existing processes for utilizing valuable constituents. My own experience leads me to believe that there is an opportunity for the wider use of pyrometallurgical concentration—either with carbonaceous smelting or sintering, pyritic smelting or electrothermic smelting—and in the last few years I have advocated the use of such processes for the preliminary treatment of the zinc carbonates and silicates of Leadville, and other base-metal ores.¹

All of those who have been present at this symposium appear to be in harmony in the opinion that whether any broken mass of rock is or is not an ore, depends on where it is, who owns it, and on the current market price of its valuable constituents, as well as on the skill and knowledge of the metallurgists who handle it. Among the environments necessary for the survival of metallurgical enterprises may be mentioned sufficient capital, a favorable location and good administrative and executive management. Any enterprise may fail if any one of these conditions is lacking.

6.—A hand magnifying glass is generally sufficient to determine how far mechanical processes will apply, or, if not, a small-scale test can be made in a metallurgical laboratory. In hydrometallurgical processes it is often of importance to know just how the various constituents are associated in the ore. In this case microscopic examination is very useful to supplement chemical analysis. But such examinations and small-scale tests need only be made once for a given ore; that is, until there is a change in the material treated. Yet I have known of cases where silicate of copper, existing in very small quantities in a silicious gangue, has been treated under the supposition that the copper existed as carbonate; also of silicates of zinc which were supposed to be carbonates; and of gold in sulphides which was supposed to be free. In short, no available means should be neglected to learn all we can about the ore to be treated before we reach or pronounce a judgment. From the nature of the case, such microscopic examinations of small-scale tests can best be made by specialists who have exceptional training and laboratory equipment.

Estes Park, Colo.

L. D. Godshall.—1.—There is a complex ore problem. In my opinion a complex ore is any ore which contains

¹The Utilization of the Zinc Carbonates and Silicates of Leadville, Colo., *Proceedings of the Colorado Scientific Society*, Vol. X, pp. 85-98. A Zinc Retort with a Copper Bottom, this Journal, Aug., 1912, p. 463. Igneous Concentration of Metallic Values from Mixed Sulphides, this Journal, April and May, 1914, pp. 250 and 307.

a valuable metal or metals difficult to save. Such complex ores may include:

(a) An intimate mixture of base-metal sulphides containing lead, zinc, iron and sometimes copper, with or without gold and silver, a small or large amount of gangue material, and presenting more or less difficulty in the concentration or separation of the various minerals by reason of crystalline texture or insufficient variation in specific gravity of the minerals to be separated.

(b) A single metal like gold or silver, in a gangue too silicious or expensive for direct smelting, but presenting serious difficulties in concentration, amalgamation or cyanidation, by reason of part or all of the metal being contained in a mineral too minutely disseminated, or easily slimed in crushing, or by having present in the ore other constituents like manganese, tellurium, etc., which may interfere with the process to be used.

2.—Many of these so-called complex ores are amenable to present methods in the hands of skilled operators. There is always a need for new methods of treatment as well as a need for improvements in present methods. The need for new methods can be illustrated by the present work at Chuquicamata; the need or value of constant improvement in present methods, by the slime treatment at Anaconda.

3.—Large mines or extensive deposits of any ore are scarce, and inasmuch as large ore-bodies present great commercial possibilities if economically treated, much more effort has been expended trying to solve the problem of correct treatment for such ores than for small and relatively unimportant bodies of ore. There are many mines capable of producing from 10 to 50 tons of ore per day if suitable methods of treatment now known were properly used.

4.—The nature of ores which are commonly termed refractory should, I think, be considered as apparent and real.

Many ores commonly termed "refractory" are so only because of inefficiency in the treatment applied to them, due to ignorance and bad management.

With some ores the refractory nature is real, and evidently not to be overcome by means of present known methods. Such instances would represent the extremes as described in the above definition of a "complex ore."

5.—In the comparatively few cases representing the extreme refractory ores, it seems evident that we must look for an improvement in our present methods of separation, mechanical or chemical, by fire or electricity, or else discover methods or processes not yet existent.

For the great majority of so-called refractory ores found all over the West in mines capable of producing, as above stated, from 10 to 15 tons per day, we must look for greater efficiency with our well known processes of today. To obtain this greater efficiency the small operator must be educated to seek the assistance of experienced metallurgists and engineers in order to get started properly. The large company or the large property will have talent and capital at hand to solve almost any difficulty capable of being solved, and one or half a dozen failures will not prevent the big problem from final solution. With the small operator the case is very different. In the first place he has not the capital necessary to retain, for any great length of time, the high class engineer or metallurgist, and one mistake often puts him and his company out of commission. It is also a well known fact that the small operator who can least afford to try new-fangled methods is in very many cases the very first to do so.

There are numerous monuments in every camp in the West illustrating this sad feature.

The difficulty in successfully handling a small output is very great, and recognized to such an extent that large companies will not consider small properties on account of the difficulty in keeping operating expenses down. It is possible to build, and I believe the near future will see, small plants as complete and almost as economical as our large ones; and when so built are equipped with the machinery and process adapted to the ore, and operated with the same conscientious care and detail as the large plant, we will consider many of our so-called complex ores anything but complex.

6.—I consider microscopical examination simply an aid to the visual examination of the ore. In concentration or separation it is necessary, of course, to have the crystal of the mineral we aim to save or separate free from the gangue or other mineral. If the microscope shows crystals of a certain size, we can crush the ore to that size, or if the crystals are so small that the freeing of same would require the practical sliming of the ore, we know before we make the attempt that concentration or mechanical separation will not be successful.

Tecopa, Cal.

* * *

Editorial Summary

Impressions sometimes become settled convictions without sufficient warrant or evidence, and occasionally it is worth while to stop and make inquiry into a condition to see to what extent current opinion represents the truth. For some years past it has been a simple expedient to attribute depression in the western mining industry to "complex" ores for which no suitable method of treatment was known; at least this has been assigned as one of the contributing causes. "Complex ore" became the ready excuse for idle mines, lack of ore and unsuccessful mills, as well as the convenient explanation for a multitude of metallurgical sins.

We are not even intimating that really complex ores have not been discovered, or that they do not still present problems in metallurgy; but it seemed to us quite likely that some phases of the situation had been overstated or misrepresented through ignorance, while the true and more hopeful aspect of the case had not been expressed. In other words, it seemed likely that some of the general and popular impressions regarding the complex-ore problem had been created by radical spirits who either were not aware of, or did not appreciate, the constructive work of those who viewed the situation more conservatively.

Believing that a widespread public expression of opinion on the subject from many different points of view would be helpful and valuable, we sought the cooperation of prominent metallurgists and have presented their views. That there is striking unanimity in their attitude on some points, and but little diversity of opinion throughout, suggests the belief that we have secured a fair composite view of the whole situation. In geographical distribution the replies cover the whole country; in personnel of contributors they represent diversity of viewpoints and interests.

1.—All are agreed that there is a complex-ore problem, having reference to the economic treatment of mixed base-metal sulphides containing gold and silver. Several contributors emphasize the fact that there are many such problems instead of one; that neither ores nor processes are twice alike, and that each must be considered as a separate problem. Mr. Thomson considers the problem less serious and not as general

as is commonly supposed, having in mind no doubt the exaggerated ideas as to the available quantity of refractory ores. In this he is supported by Mr. Swart who regards the problem as not wholly metallurgical, but closely related to the economics of mining—"the location, size and character of the ore-bodies." This takes the burden partly off the metallurgist who, in Mr. Swart's opinion, will successfully treat the ore "if there is enough of it." Mr. Bleeker voices a similar sentiment, and at the same time casts reflections on the alleged abundance of complex ores, when he says that "if the mine is not exhausted by the loss of this quantity of ore" (necessary to make a test) there is hope of solving the problem. Mr. Clevenger, on the other hand, viewing broadly the economics of metallurgy, believes that the problem always is with us "so long as the percentage of extraction is below 100 and the working costs are greater than 0."

As to what constitutes a complex ore there is also a general agreement, although it is apparent that a wide variety of ores can be included in the term. Generally speaking they contain sulphides of lead, zinc, iron or copper, with or without gold and silver, zinc being regarded as a characteristic constituent. Prof. George and others cite a wide variety of complex ores.

From the ore-dressing point of view Mr. Guess and Mr. Collins regard as complex, an ore containing several metals which have to be separated, and which are difficult to separate into marketable products; and which, we might add with Prof. Richards, "would have greatly increased value if separated." This implies, however, the *possibility* of such separation, even though it may not be done as satisfactorily or profitably as might be wished.

An extension of this classification covers similar ores of such physical characteristics as to *preclude the possibility of any separation of minerals* by ore-dressing devices. Hence, Mr. Bleeker and Mr. Johnson apparently regard ores as complex when they "cannot be treated by standard mechanical devices," or do not "admit of separation by mechanical methods." Mr. Bell cites an excellent example of this kind of complex ore.

This distinction between complex ores according to their amenability to mechanical methods of separation is more relative than exact, because as Mr. Croasdale points out, many of the ores now profitably treated by modern mechanical methods are subject to great losses; and sometimes the penalties on undesirable elements become prohibitive, as suggested by Mr. Ionides. The mere fact that ore-dressing methods are being used on some ores does not greatly affect their classification as complex; so that whether an ore can or cannot be treated mechanically, the problem remains of conserving resources, on the one hand, and making new ores available, on the other.

The smelter's point of view is reflected by Messrs. Austin and Traphagen. The former "might limit the definition to cover mixtures, in the treatment of which the extraction of one metal interferes with the recovery of another," and cites an ore containing zinc blende in addition to sulphides of lead and copper. Dr. Traphagen mentions the same fact and says that "our metallurgical processes save but a few metals and sacrifice others of value." Mr. Clevenger points out the flexibility of the smelting process and its ability to treat a wide variety of ores, but he recognizes the inevitable loss of some constituents, notably zinc.

2.—In the discussion on the skilful use of present methods (ore-dressing and smelting) versus the need of new processes, we find a tendency to support the former while acknowledging the latter. Here we come

squarely up against the classification of complex ores into those which can and cannot be treated by mechanical processes.

Mr. Swart is quite certain that "by far the greater proportion of (complex) ore can be successfully (profitably) handled by mechanical methods," in which opinion Mr. Godbe concurs. Mr. Collins regards these ores as "amenable to (imperfect) separation by known methods or combination of methods." Prof. Richards thinks that "some of these ores would yield to present processes skilfully applied," and Mr. Thomson states that "such ores are in part amenable to treatment by present processes when properly conducted." These and other contributors recognize the need for more skilful operation, and the possibility of thereby improving results in ore-dressing; but an implied apology is made for the inherent limitations of the methods themselves.

Mr. Skinner, however, comes out squarely with a defense of ore-dressing methods and a strong criticism of the inefficient way in which they are used at many mills. "It is not a fact that poor methods make the losses high, but that the handling of ore-dressing methods is deplorable. * * * The poor quality of mill operation is no doubt responsible for the notion that there is a complex-ore problem." His comments on the operation of average mills are worthy of consideration. He recognizes, of course, that "it would be very foolish to say that some new procedure would not prove, in some cases, more desirable than the known methods," but it is his opinion that "with the possible exception of electric zinc smelting," and under conditions known to him, "complex ores should be treated by simple ore-dressing followed by the old procedures, as against any new chemical or other sort of scheme outlined to date."

On the other hand, and relating particularly to those ores which all agree are not amenable to mechanical processes, we find a demand for new methods. As Mr. Canby aptly says, "the amenability of these ores to present processes is not a question of operating skill." Dr. Traphagen acknowledges the possibility of improving present practice by more skilful operation, but does not see "as much room for progress in present methods, particularly mechanical processes, as in the development of new methods." Mr. Ionides calls attention to the combined losses in ore-dressing and smelting, and Mr. Croasdale suggests that "it is scarcely conceivable that the cost of treatment in a more direct and refined metallurgical process, whatever it may be, will exceed the cost plus the losses sustained by mechanical concentration and smelting."

3.—Whether there are many mines now idle which could produce a considerable tonnage of complex ore if suitable methods of treatment were known, is, we believe, one of the points on which popular opinion has been in error. The consensus of opinion of our contributors is that there are not many such mines. In other words, complete idleness in the mining of complex ores is likely to be due not so much to the real lack of treatment methods as to other economic causes. Mr. Swart sees the real problem in "small, scattered and dissimilar" ore-bodies, and attributes idleness to "such conditions as inaccessibility, heavy snow, poor transportation, high freight rates, high fuel, distance from market, lack of water, poor financing, bad management, ignorance, and improper mining and milling methods." This is an array of economic conditions outside the control of the metallurgist, and they suggest that the lack of a process is not the main reason for idleness of complex-ore mines.

As to the contrary opinion gained by Mr. Johnson from letters received as the result of "a two-month's

campaign which had for its object the gaining of information as to the need of a process" for treating these ores, we question the value of such information. The average mine owner is a wonderful optimist regarding his property, and frequently obsessed with the idea that all his "mine" needs is a "process." Only those who have had experience can sympathize with Mr. Clevenger when he says that "it is no unusual thing for tremendous deposits * * * to shrink into nothing upon careful examination." Probably others have had the experience of Mr. Thomson who has examined many such alleged mines and found that "quantity of quality of ore was lacking in every case."

All this, however, does not preclude a genuine need for metallurgical improvement, even at mills now operating; for the method treatment, while profitable, may be yielding poor economic results. It is recognized also that there are some mines, although they are few, at which production is deferred awaiting metallurgical development.

4.—The object of our fourth query was to see whether any particular quality—physical, chemical or both—could be considered as characterizing complex ores. The replies are fairly in agreement, and a number of good points are brought out. From the ore-dressing point of view the following qualities may cause ore to be classified as complex: Intimate physical association of the constituent minerals; fineness of crystallization and friability of minerals; narrow margin between the specific gravities of sulphide constituents; similarity of specific gravity of mineral and gangue; chemical combination of different metals in a single mineral; similar action of minerals in flotation; and equivalent electrical and magnetic properties of minerals.

The economic phase is suggested by Mr. Collins, who says "it is mainly a matter of costs and market values"; and by Mr. Bleecker who observes that "an ore is not necessarily worth treating because the total values foot up to ten or twenty dollars per ton."

On the chemical side, those who seek to lay the cause of complexity at the door of a single constituent element are unanimous in selecting zinc as the offender. This metal has to bear the brunt of losses and penalties, and its recovery is one of the fundamental features of newly proposed processes. Prof. Richards speaks of zinc as "the worst stumbling block in the metallurgy of complex ores," and Mr. Johnson believes that "the great importance of a process that will *save the zinc* is manifest." Mr. Austin calls attention to the obstacles presented by zinc in the smelting process, and comments on its loss and that of accompanying metals.

5.—When we come to consider what processes may be regarded as possible solutions of the complex-ore problem, we find the greatest diversity of opinion. Excluding those opinions emanating from contributors personally interested in some process, we find two features among the balance: an expression of hope and confidence in the ultimate success of electric zinc smelting, and a favorable attitude toward hydrometallurgy.

Mr. Wiard alone anticipates that "mechanical processes will be more generally applied in the treatment of these ores." Others express more conservatively the thought that mechanical methods will hold their own for some time to come, because the newer proposals have not yet reached the stage of successful application and must await wide adoption until they have produced acceptable data from operation. It appears almost certain that in some cases preliminary mechanical concentration will have to accompany even hydro- or electrometallurgical schemes. Flotation is one of

the newer mechanical methods in which some profess to see a hopeful solution in special cases; but even here, as Mr. Skinner points out, we are benefited only in the case of one-mineral separation. Where two or more sulphides are involved, flotation does not offer so much advantage.

In fact, in the whole realm of mechanical processes, it is not one, but two or more methods in combination to which we must look for economic ore-treatment. This "interminable mechanical grooming," as Mr. Croasdale puts it, is objectionable on the score of successive losses in each step; and its abandonment has been one of the chief incentives of those who advocate new processes to yield metals at the mine.

Mr. Ionides believes that "a solution of the problem along purely mechanical lines seems doubtful, and is inclined, with Mr. Bell, to think that "hydrometallurgical and chemical means will have to be employed." Others express similar sentiments. Mr. Clevenger is especially impressed with the possibilities of hydrometallurgy, which is coming to be of rapidly increasing importance and promises to be as useful in the recovery of non-ferrous metals as the cyanide process is for gold and silver. He sees in this line of development a possible solution of not only the complex-ore problem, but also the smelter-smoke problem. Obstacles to successful hydrometallurgy do not seem insurmountable to him in view of the remarkable work done at Cobalt in treating complex silver-cobalt-nickel-arsenic ores by cyanidation.

The objections to hydro- and electrometallurgy are voiced by Mr. Swart, who says that "plant cost on most of the proposed chemical and electrical methods is prohibitive for small mines," and by Mr. Skinner, who objects to "the handling of salts of high heats of formation in large volume of solution, calling for a high investment cost and demanding expensive chemicals."

Of the special processes proposed, Mr. Johnson is partial to electric smelting; Mr. Scibird and Mr. Ionides to some form of chlorination, and Mr. Bretherton to ammonia-carbon dioxide.

Speaking from the standpoint of a smelter, Mr. Austin is of the opinion that "it would be hazardous to suggest" along what line reduction methods will develop, but he believes it will be "not in the line of pyrometallurgy." It is interesting to compare this with the opinion expressed later by Mr. Clerc, whose experience leads him "to believe that there is an opportunity for the wider use of pyrometallurgical concentration" by modified forms of smelting or sintering. Mr. Clerc has in mind, as a particular case of the general problem, the lean oxidized ores of zinc and iron which, while not within the class of complex sulphides nevertheless present a problem of similar economic importance. These ores require some form of concentration in order to raise their zinc content to the grade required by zinc smelters. Not being amenable to any of the ordinary methods of enrichment, fire concentration is suggested. This would produce an impure zinc oxide for further reduction in a special furnace, and it is Mr. Clerc's suggestion to so modify current metallurgical practice as to enable the smelter to co-operate with the miner in utilizing this kind of ore.

6.—The general use of the microscope is commended in examining ores and products: to determine the fitness of the former for the proposed treatment and the efficiency of the process as indicated by the latter. Such examination will aid in locating trouble and may suggest the remedy. It will be specially valuable in the case of tailings, middlings and other products of wet and dry separation processes, and in observing

changes in the character of the original ore supply. Several contributors to the symposium who are college professors state that they regularly train their students in this use of the microscope.

General.—The reader who is well posted on the subject of this symposium may feel that the tenor of the replies to our questions is about what he expected. At the same time it is worth while to have these opinions publicly expressed by competent observers, in order to crystallize the facts for the benefit of those less well informed. It is made clear that the problem is one of many phases. We cannot "use the same medicine for a number of widely different ills," as Mr. Haldane says. This is reason enough for considering the merits of all the various proposals and, above all, maintaining an open, unbiased mind. This is good advice to the promoter as well as the perspective user of new schemes. Panaceas are not favorably regarded by the well informed.

A useful hint to process inventors is given by Mr. Croasdale, who suggests that the best way to bring new processes to trial is to secure the support of operating companies that have the problem, the money and the willingness to spend it intelligently. "This can be readily done by appropriations set aside from earnings, which would virtually come from the properties themselves and not from the shareholders." Mr. Collins makes it plain, in this connection, that pioneer work in metallurgy is expensive, and that "the details of such processes (electric smelting or chlorination) should be worked out by large existing producers." The unfortunate tendency of small, inexperienced operators to try unproved processes is properly criticized by Mr. Godshall.

On the whole we believe that the symposium has given expression to many useful and constructive ideas, and has brought out strongly the spirit of willing co-operation which makes the ultimate solution of the problem seem far from hopeless. To all those who have contributed from their knowledge and experience, we express our thanks and hearty appreciation.

The Titanium Alloy Manufacturing Company announces that it has organized a Bronze Department for the manufacture of Titanium-Bronze Specialties under its various patents, and that Mr. Wm. M. Corse, formerly Works Manager of the Lumen Bearing Company, Buffalo, and lately General Manager of the Empire Smelting Company, Depew, N. Y., will be associated with the company as Manager of this department.

A composition for treating boiler feed-water, patented by Gilbert E. Bailey, of Los Angeles, Cal., consists of a mixture of graphitic iron and 1 to 4 per cent. zinc, the latter being added to the iron as it flows from a cupola. The alloy is turned into shavings or powdered.

A new platinum alloy, suitable for making scientific instruments, electrical contacts, and the like, has been patented by Exechiel Weintraub, of the General Electric Co. It consists of platinum and either tungsten or molybdenum, or the three together, platinum constituting about 20 parts of the whole. The alloy resists the action of air and has great mechanical strength.

Transvaal Gold Production.—The number of companies reporting to the Transvaal Chamber of Mines in March, 1914, was 60. The total quantity of ore milled during that period was 2,149,601 tons. There were 9662 stamps in operation, with an average duty of 8.82 tons per 24 hours. Tube mills in commission numbered 290. The yield for the month was 686,801 fine ounces gold.

The Application of Physical Chemistry to Industrial Processes*

BY WALTER F. RITTMAN

The luxury of to-day is the necessity of to-morrow; likewise the theory of to-day is the practice of to-morrow. Gayley's process of drying air for a steel furnace, the various nitrogen-from-air processes, the contact process of manufacturing sulphuric acid, synthetic indigo, synthetic tanning materials—all were in the field of abstract theory but a few years ago. To-day they are practical realities. Similarly many of the theoretical principles and processes of to-day will in all probability be realities a few years hence.

The invasion of chemistry by physics and the production of what is known as physical chemistry, promises to be a most important basis for progress in the field of applied chemistry. Whereas physical chemistry is often looked upon as one of our most theoretical subjects, it will be found to be one of our most practical as well. Its principles are useful regardless of the materials involved in the reactions, whether copper, steel, soap, glass, cement, gas, textile, or any other chemical product. Physical chemistry is described as that branch of chemistry which has for its object the study of the laws governing chemical phenomena. When these laws and their application to a reaction or process are once understood it is a relatively easy matter to select the most favorable physical conditions. The task of the chemical engineer is to produce these most favorable working conditions in an apparatus which operates on an industrial scale. A further advantage of a knowledge of theoretical principles and perhaps one to be more frequently applied is the aid such knowledge gives in avoiding fantastic so-called improvements.

The chemical engineer rarely creates new products; he deals with processes and machinery which produce quantities economically. Obviously his problems often differ from those of the laboratory chemist. The fact that a reaction is slightly exothermic or endo-thermic is of secondary consequence in laboratory experiments, but in applied engineering this fact at once determines whether the reaction should be carried out in a cooled or in a heated apparatus. The amount of heat given off in a reaction, such as the hydrogenation of a vegetable oil, is of no serious consequence in laboratory experiments, but where tons are handled the accumulated heat is sufficient to ruin any process which does not provide for its disposal. Latent heat of fusion or of evaporation is not important in the laboratory where there is always an excess of heat or cold, but in many cases this heat of fusion or of evaporation becomes all important in its influence on the cost of an industrial operation. The cost of the heat absorbed by an endo-thermic reaction seldom concerns the laboratory chemist; but it is profit or loss to the chemical engineer. The percentage of yield, and the cost per unit, are the vital questions to the engineer; they are usually not vital to the laboratory chemist, however valuable and constructive his work may be.

It sometimes seems as if the inertia of years has limited the temperature imagination of many engineers and some chemists. Theoretical considerations might suggest the broad field which comprises the several thousand available degrees above the boiling point, as well as the 273 degrees below the freezing point of water. Likewise we are prone to overlook the great advantages which sometimes may be derived from the application of pressures greater or less than the one

*A paper presented before the American Institute of Chemical Engineers, Troy, N. Y., June 17th, 1914.

atmosphere which surrounds us and with which we are so familiar.

Because of the numerous possibilities in the application of physical chemistry to industrial processes, I must greatly restrict myself in dealing with the subject. Some of the most interesting parts deal with equilibrium relationships, phase rule applications, radioactivity, energy considerations and electrolytic reactions. Excellent examples illustrating the successful application of each can be found, but to-day I shall deal in some detail only with the one mentioned first; i.e., equilibrium relationships.

I shall not attempt to deal with every branch of modern production which involves the equilibrium relations of physical chemistry, nor shall I attempt to advance speculations as to future applications of equilibrium relations in industry. The attempt will be confined to successful present-day applications, by way of examples. However familiar these processes may be, I hope that there will be at least something interesting, if not new, in pointing out that these familiar processes have a purely theoretical aspect. In fact, dealing with them historically indicates that they have all developed out of the most abstract theoretical reasoning into the practical machinery of economical production.

Oxidation of Nitrogen From Air

It is known that at room temperature there is no perceptible union of the nitrogen and oxygen of air; it is known that at temperatures as high as 3000° C. only a partial union takes place; it is known that the amount which does unite is a function of the temperature. That is, at each temperature there is a definite percentage of nitric oxide formed, and equilibrium exists between the combined and uncombined constituents. In other words, the tendency of the uncombined constituents to combine at any particular temperature is exactly counterbalanced by the tendency of the combined constituents to separate at that temperature.

There is a true equilibrium. Experiment has proven that when air analyzing 79.1% N₂ and 20.9% O₂ is brought to equilibrium at 2400° C. the resultant mixture analyzes 2.23% NO, 77.98% N₂ and 19.78% O₂, i.e., 1.115 per cent. of an atmosphere each of nitrogen and oxygen have disappeared in the formation of nitric oxide. Further let it be clear that this 2.23 per cent. of NO obtained at 2400° C. is not an accidental figure; it will always be the same when air of the above composition is brought to equilibrium at 2400° C.

This fact makes it possible to calculate the equilibrium constant for nitrogen, oxygen and nitric oxide at 2400° C.

$$\text{N}_2 + \text{O}_2 \leftrightarrow 2\text{NO} - 43,200 \text{ cal}$$

$$K_{2400^\circ\text{C}} = \frac{p_{\text{NO}}^2}{p_{\text{N}_2} p_{\text{O}_2}} = \frac{(0.0223)^2}{(0.7798)(0.1978)} = 0.0032$$

where p represents the partial pressures of each of the three constituents, i.e., the part of the whole pressure exerted by each.

The constant K which joins these partial pressures has a definite numerical value for each definite temperature. The square of the partial pressure of NO, divided by the product of the partial pressure of N₂ multiplied by the partial pressure of O₂, for any mixture of these three constituents in equilibrium at 2400° C. will be equal to 0.0032. Through the application of thermodynamic principles¹, it is possible to calculate the value of K' for any other temperature from

the above experimentally determined value of K for 2400° C.

From this value of K' for any other temperature, as 3000° C. for example, it becomes a simple matter to calculate the yield of NO which will be obtained from any initial mixture of nitrogen and oxygen brought to equilibrium at that temperature. Percentages of N₂, O₂ and NO which satisfy the equilibrium relationship for any temperature will always be obtained when these constituents are brought to equilibrium at that temperature. Further, the reaction is reversible, and reaches the same results from either direction.

A number of values for equilibrium constants of this reaction at different temperatures have been calculated. From these values the percentage yield of NO from air have been calculated, and the calculations have been checked, as follows:²

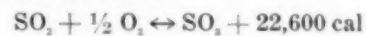
TABLE I—COMPARISON OF CALCULATED AND OBSERVED VALUES OF EQUILIBRIUM CONSTANTS FOR THE
 $\text{N}_2 + \text{O}_2 = 2\text{NO}$ REACTION
NO (calculated from

| Temperature Degrees C. | values of K Per cent. | NO (observed) Per cent. |
|---------------------------|----------------------------|----------------------------|
| 1538 | 0.35 | 0.37 |
| 1604 | 0.43 | 0.42 |
| 1760 | 0.67 | 0.64 |
| 1922 | 0.98 | 0.97 |
| 2307 | 2.02 | 2.05 |
| 2402 | 2.35 | 2.23 |
| 3060 | 5.00 | .... |

It is observed that until 3000° C. is exceeded the yield of NO is below five per cent. The above clearly indicates how theoretical considerations show the limits of a reaction as well as the most favorable conditions for its industrial application. The oxidation-of-nitrogen process obviously is limited in practical application to localities where large quantities of cheap electric power are available.

Contact Process of Manufacturing Sulphuric Acid

The contact process of manufacturing sulphuric acid, considered from the equilibrium view point, can be expressed by the equations:



$$K = \frac{p_{\text{SO}_3}}{p_{\text{SO}_2} p_{\text{O}_2}^{1/2}}$$

A few values³ of K are given in Table II.

TABLE II—VALUES OF EQUILIBRIUM CONSTANTS AT DIFFERENT TEMPERATURES FOR THE $\text{SO}_2 + \frac{1}{2} \text{O}_2 \leftrightarrow \text{SO}_3$ REACTION

| Temperature Degrees C. | K_p (experimental) |
|---------------------------|----------------------|
| 400 | 580.0 (calculated) |
| 450 | 188.0 |
| 515 | 65.4 |
| 600 | 14.9 |
| 800 | 1.81 |
| 900 | 0.57 |

Upon calculating the maximum yields of SO₃ obtainable at the different temperatures from the various values of K , it is observed that the yield rapidly decreases as the temperature increases. This is in contrast to the nitric oxide illustration where the yield of NO from N₂ and O₂ increases with the temperature. As the temperature increases in the SO₂ + O₂ reaction the values of the equilibrium constants decrease rap-

¹Nernst & Finckh, Z. anorg. Chem., 1905, p. 116; *ibid.*, 1906, pp. 212, 229.

²Nernst Theoretical Chemistry, seventh German Edition, pp. 675-6. Morgan, Elements of Physical Chemistry, 5th edition, in press.

³Nernst, Zeit. anorg. Chem., 1906, pp. 213-228. Zeit. f. Elek., 1906, p. 257, p. 529. Jellinek, Zeit. anorg. Chem., 1906, p. 229-276. Nernst-Finckh, *ibid.*, 1905, p. 116.

⁴Knietsch, Berichte 1901, p. 4069. Bodlander u. Koppen, Z. f. Elek. 1903, p. 787. Bodenstein u. Pohl *ibid.*, 1905, p. 373.

idly. At temperatures below 400° C., however, the union of SO₂ and O₂ is too slow for an industrial process. At this temperature there is but a slight sacrifice of the percentage of SO₂ and O₂ combination.

Temperature, however, is not the only thing which influences a reaction of this nature. Without entering into a mathematical discussion of the influence of pressure, we can recall LeChatelier's principle: that pressure stimulates those reactions involving contraction, while vacuum encourages those reactions involving expansion.

Further, temperature and pressure do not complete the factors influencing chemical reactions where equilibria are involved. The third and important factor is the relative concentration of the various reacting elements. The SO₂ reaction furnishes an excellent example showing the influence of the concentration of the combining reagents. Observing the mathematical expression for the equilibrium relationship,

$$K = \frac{p_{SO_2}}{p_{SO_2} p_{O_2}^{1/2}} \text{ or } \frac{p_{SO_2}}{p_{SO_2}} = K \sqrt{p_{O_2}}$$

it becomes evident that the relative yield of SO₂, with respect to SO₂, increases as the partial pressure of oxygen increases, since the value of K for any given temperature does not change. This can best be observed by giving K the arbitrary value 200, and assigning to O₂ the partial pressures 0.25, 0.50, 1.00 and 2.00:

Then $\frac{p_{SO_2}}{p_{SO_2}} = 200 \times \sqrt{\text{partial pressure } O_2}$ and the ratios desired are given in Table III.

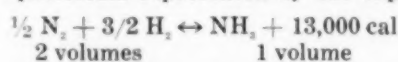
TABLE III—SHOWING EFFECT OF INCREASING THE CONCENTRATION OF ONE OF THE CONSTITUENTS IN AN EQUILIBRIUM

| Partial pressure of oxygen | Ratio of SO ₂ to SO ₂ |
|----------------------------|---|
| 0.25 | 100 |
| 0.50 | 141 |
| 1.00 | 200 |
| 2.00 | 282 |

This influence of an excess of oxygen is of practical value and is used in the commercial manufacture of SO₂.

Synthesis of Ammonia from H₂ and N₂

Another illustration of the factors entering into chemical equilibria involving temperature, pressure, and concentration is the Haber method of manufacturing ammonia from nitrogen and hydrogen*. The synthesis of ammonia from nitrogen and hydrogen depends upon the equilibrium represented by the expression:



$$K = \frac{p_{NH_3}}{p_{N_2}^{1/2} p_{H_2}^{3/2}}$$

A few investigated values for K are given in Table IV.

TABLE IV—EQUILIBRIUM CONSTANTS FOR THE AMMONIA SYNTHESIS

| Temperature Degrees C. | K (experimental) | K (calculated) |
|------------------------|------------------|----------------|
| 700 | ..... | 0.00068 |
| 800 | 0.00033 | 0.00036 |
| 1000 | 0.000148 | 0.000145 |

Haber[†] found that as the temperature rises above

500° C. the yield of NH₃ is low, while below 500° C. the rate of reaction is too slow. He eventually so perfected his experimental apparatus that his yields of NH₃ permitted him to calculate K from experimental data and compare the same with theoretical values. The close correspondence of the theoretical and actual values above indicate how experiment reinforced by theory will often show what can be expected in practice better than imperfect experimental results without theory. Without theory, in fact, Haber would never have known whether his experimental work was perfect, imperfect, or worthless.

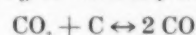
In this ammonia reaction, equilibrium relations are such that when the reaction is practiced under atmospheric pressure the maximum yield is not sufficient to warrant industrial application. A yield of less than one quarter of one per cent. is of little more than scientific interest. Through the introduction of increased pressures, however, the contraction from two volumes to one volume is greatly favored and the process yielding twelve per cent. at once becomes of decided commercial interest. In the oxidation-of-nitrogen process, on the other hand, there is no change in the number of volumes, and pressure is without influence on the reaction. This pressure influence in connection with equilibrium relations is strikingly shown in table V.

TABLE V—PERCENTAGE AMOUNT OF NH₃ IN THE EQUILIBRIUM OF THE REACTION N₂ + 3H₂ = 2NH₃

| Pressure in atmospheres | Temperature Degrees C. | | | | |
|-------------------------|------------------------|--------|--------|--------|--------|
| | 550 | 650 | 750 | 850 | 950 |
| 1 | 0.0769 | 0.0321 | 0.0159 | 0.0089 | 0.0055 |
| 100 | 6.70 | 3.02 | 1.54 | 0.874 | 0.542 |
| 200 | 11.9 | 5.71 | 2.99 | 1.68 | 1.07 |

Other Applications of Equilibrium Relations

The equilibrium relationship between reacting agents persists throughout all chemical phenomena. The relative amount of CO₂ to CO issuing from a furnace is primarily a function of temperature and pressure, and is influenced by the machine only insofar as the machine influences these variables. The equilibrium between CO₂ and CO in the presence of carbon for any temperature is reached regardless of whether one starts with CO or with CO₂, or with any mixture of the two.



$$K = \frac{p_{CO}^2}{p_{CO_2}}$$

TABLE VI—EQUILIBRIUM RELATIONS BETWEEN CO AND CO₂ IN PRESENCE OF CARBON

| Temperature °C | Per cent by volume | |
|----------------|--------------------|-----------------|
| | CO | CO ₂ |
| 450 | 2 | 98 |
| 750 | 76 | 24 |
| 1050 | 99.6 | 0.4 |

Typical examples of this relationship are found in the kitchen stove, the factory boiler, the blast furnace, the gas machine or the open-hearth furnace. Doubling the size of the blast furnace changes the relative amounts of CO₂ and CO only so far as doubling the size of the furnace influences the temperatures in the various reacting zones. With increasing temperature the percentage of CO increases, with decreasing temperature the percentage of CO₂ increases.

In the blast furnace, for instance, not only are the CO and CO₂ in equilibrium, but the various oxides of iron are likewise in equilibrium with carbon, CO and CO₂, as well as with one another.

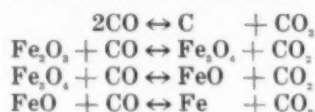
*Zeitsch. f. Elek., 1913, p. 53.

†F. Haber, Thermodynamics of Technical Gas Reactions.

‡F. Haber, Jour. Soc. Chem. Ind., 1914, p. 49.

§J. Mellor, Modern Inorganic Chemistry, p. 713.

Consider the blast furnace reactions,



from the equilibrium point of view; there is found to be a vital relationship between them. On first sight a series of equations of such a nature looks very complex, but on the application of equilibrium relationships, formulated by means of the phase rule diagram, it is found to be relatively simple and clear.

Experimental work⁹ has been done on these relationships, from which it is possible to plot the diagram of equilibria.

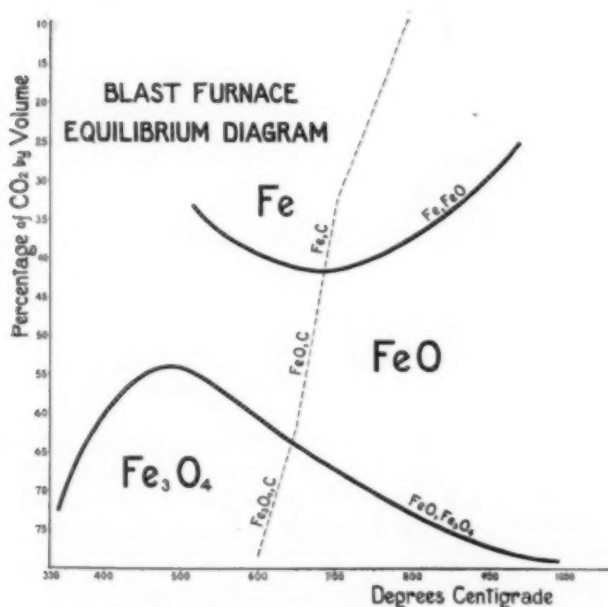


FIGURE 1—BLAST FURNACE EQUILIBRIUM DIAGRAM, SHOWING RELATIONS BETWEEN C, CO, CO₂, Fe, FeO, AND Fe₃O₄.

All of the reactions are reversible; their direction is entirely a function of temperature. From the diagram the fields of stability of Fe, FeO and Fe₃O₄ in the presence of CO and CO₂ for the temperatures shown can be observed. It can be observed, for example, that FeO at 650 deg. C. is not stable in the presence of more than 65% or less than 43% CO₂. It becomes evident that in the reduction of FeO to Fe a maximum of CO₂ in the flue gases is obtained when the reaction takes place at about 675 deg. C. and that this percentage of CO₂ decreases as the temperature increases. The diagram indicates that most of the reduction takes place in the cooler part of the furnace.

Coefficient of Partition or Distribution

Equilibrium conditions also prevail in the more purely physical world as well as in chemistry. A solution which divides itself between two immiscible solvents will always be found in a definite concentration in both solvents, and there will always be a definite ratio between the concentration in each. This ratio is known as the partition or distribution coefficient.

I will cite first the laboratory example dealing with iodine, water and carbon disulphide. Iodine is slightly soluble in water and much more soluble in carbon disulphide, while water and carbon disulphide are practically insoluble in each other.

Suppose we have both water and carbon disulphide in one vessel and add some iodine. It has been observed from experiments that the concentration of iodine in the carbon disulphide is 588 times the concentration of iodine in water. In other words,

$$K_{\text{iodine}} = \frac{C_{\text{CS}_2}}{C_{\text{H}_2\text{O}}} = 588$$

In similar manner iodine divides itself between ether and water so that the concentration of iodine in the ether is 200 times the concentration of iodine in the water.

$$K_{\text{iodine}} = \frac{C_{\text{ether}}}{C_{\text{water}}} = 200$$

Similar examples can be found in the distribution of acetic acid between benzene and water, benzoic acid in benzene and water, succinic acid in ether and water, acetic acid in chloroform in water, saccharin in ether and water, acetanilid in ether and water, vanillin in ether and water, or acetanilid in chloroform and water.

This aspect of equilibrium is finding application in analytical chemistry, more especially in that branch dealing with alkaloids.¹⁰ Through its application the haphazard washing out process in alkaloid work is replaced by one of mathematical precision.

Technical application can be found in Parke's process for extracting silver from lead. Silver is very much more soluble in zinc than in lead, whereas lead and zinc are only slightly soluble in each other. The lead containing silver is melted and thoroughly mixed with a small proportion of zinc. The zinc floats to the top, carrying with it in solution practically all of the silver, and on cooling solidifies while the lead is still molten. The zinc containing the silver is then skimmed off, and these two constituents separated.

Lack of time forbids the consideration of the equilibrium relationships existing in the ionization of acids, bases, and salts. Their application in analytical chemical methods is to-day a reality, their technical application promises much.

Equilibrium Relations Are of General Application

The equilibrium or kinetic relationship is accepted and used by theoretical chemists, and is believed to prevail in practically all fields of chemistry. When considered in mathematical units it changes qualitative suggestion into quantitative information. Equilibria deal with yields in terms of percentages or weights, they deal with temperature, pressure and concentration in numerical terms. When so applied, they are concrete and cease to be more theoretical than any other mathematical statement.

Equilibria exist between reacting agents in solution; between reacting liquids; between liquids and vapors; solids and liquids; solids and gases; between gases which react chemically; between the concentrations of a solute divided between two immiscible solvents; in the ionization of acids, bases and salts, in hydrolysis and saponification; in fact in all the chemical and physical phenomena with which the chemist or the chemical engineer deals. The industrial development and application of physical chemistry, including this equilibrium principle, is only partially realized to-day; its further development and application seem to depend largely upon competition and necessity, and the stimulus they offer to the inventive faculties of chemical engineers as the leading specialists in this most promising field of our science.

Chemical Engineering Laboratory,
Columbia University, New York.

⁹Baur und Glaessner, *Zeit. physik. Chem.*, 1903, p. 354.

¹⁰J. W. Marden, *Jour. of Ind. and Eng. Chem.*, 1914, p. 315.

Recent Chemical and Metallurgical Patents

Iron and Steel

Method of Coating Iron with Zinc.—In the manufacture of galvanized pipes for electric conduit purposes, Mr. Peter McIlroy, of Pittsburgh, Pa., has patented an improved process which he has assigned to the Enamelled Metals Co., of Sharpsburgh, Pa. The pipe is successively immersed in alkali, acid and lime baths to prepare it for the coating of zinc. The electroplating is accomplished in two operations: first, by depositing a "strike" coat of copper and zinc in the proportion of 40 per cent copper and 60 per cent zinc; and second, by applying over this a coating of zinc. The inventor claims that this improved "strike" coat enables him to produce a coated pipe that will not be subject to corrosion. Pipe thus prepared is whiter and more uniform in appearance than other similarly coated pipe. (1,096,636, May 12, 1914.)

Gold and Silver

Continuous Slime Thickening Apparatus.—In Fig. 1 is shown an apparatus patented by Mr. John E. Rothwell, of Butte, Mont., and assigned to the Colorado Iron Works Co., of Denver, Col. The object of the device is to continuously thicken a slime pulp, as in the cyanide process for gold and silver recovery, and to separate clear solution from the thickened pulp. The apparatus comprises a hollow cylinder 3, open top and bottom, supported in a cylindrical vessel with

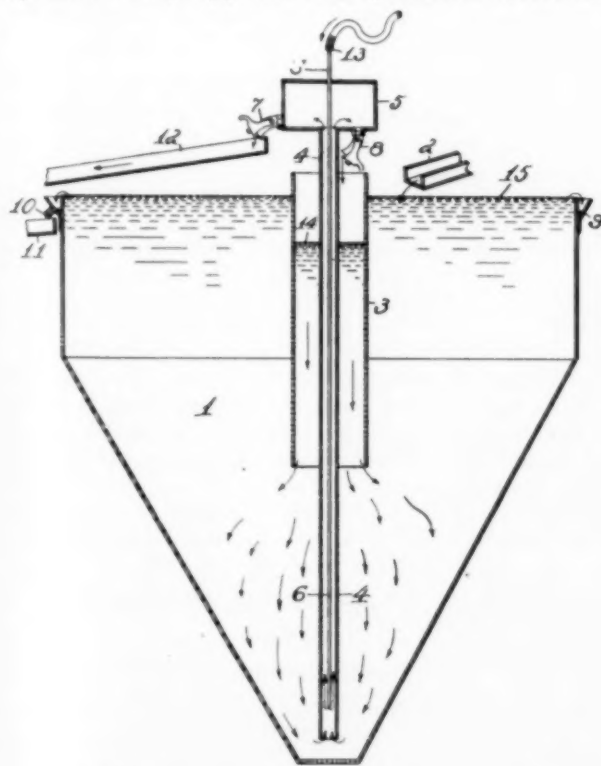


FIG. 1—CONTINUOUS SLIME THICKENER

a conical bottom. An air lift is centrally disposed in the tank, having a receptacle at its upper end into which the lifted pulp is discharged, and from which it may be diverted through gates into a launder 12 or back into the inner cylinder. An overflow launder 9 surrounds the upper edge of the tank, to receive clear solution after it has been separated from the thickened pulp.

In operation, a mixture of fine solids suspended in liquid is fed into the tank through the launder 2. The solids settle and the solution overflows. The settled solids accumulate in the cone and are elevated

by the air lift. The latter is operated at a greater capacity than is necessary to supply the amount drawn off through launder 12, and this part returns to the cylinder 3. By this means the thickened pulp is kept in circulation and is prevented from accumulating in hardened masses on the conical side of the tank. A diaphragm pump may be used in place of the air lift. An application of the invention is to continuous decantation in the cyanide process, wherein thickened pulp of uniform density is withdrawn from the decantation vessels. (1,099,396, June 9, 1914.)

Filter Leaf and Process of Dislodging Slime Cakes.

—A filter leaf from which the slime cake can be dislodged by means other than the application of reverse or internal fluid pressure, has been patented by Mr. George W. Shepherd, of New York City. The patent is assigned to the Butters Patent Vacuum Filter Co. In Fig. 2 is shown a side and end view of the leaf, and a plan of the water pipes used for dislodging the cake. The leaf consists of the usual pipe frame 5, perforated along the lower side and con-

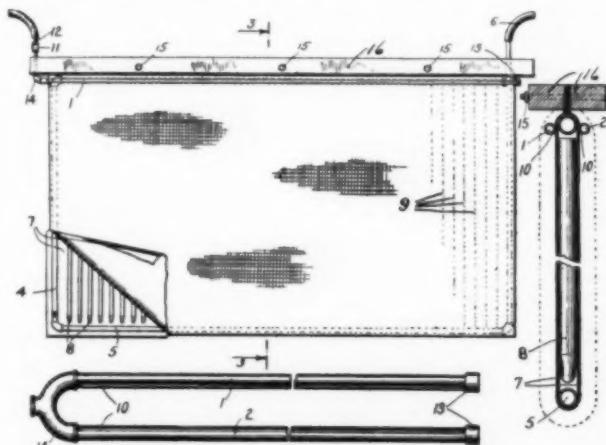


FIG. 2—FILTER LEAF

nected at 6 with a source of vacuum. A sack of filter fabric surrounds the frame and contains the customary slats 8, between which the two faces of fabric are stitched together as shown at 9. The upper edges of the fabric are held between the headers 16, bolted together at 15. Extending lengthwise of the frame, below the headers and outside the fabric are the pipes 1 and 2, slotted or perforated as at 10. These pipes join in a fitting 14 and are connected with a source of water under pressure. As shown by the dotted outline in the end view at the right, these water pipes are covered by the cake when it is formed on the fabric. After the cake has been formed and washed and is ready to be discharged, water is forced into the pipes 1 and 2 and directed by the slot or perforations between the cake and fabric, thereby causing the former to fall off. The feature of the patent is the admission of fluid beneath the surface of the cake. (1,096,132-3, May 12, 1914.)

Zinc, Lead and Copper

Separation of Bismuth from Copper.—Mr. William Thum, superintendent of the lead refinery of the United States Metals Refining Co., Grasselli, Ind., has patented a process for the recovery of bismuth from the by-products of lead refining. The process is applicable also to bismuth-bearing refuse material, oxide slags from the treatment of bismuth-bearing copper, flue dust of copper furnaces and converters and from anode slime from electrolytic lead refining from which the antimony, arsenic and lead have been cupelled. Any material showing a concentration of bismuth in

the presence of copper can be treated by the process, which consists in converting the copper into matte by fusing with an alkali sulphide, leaving the bismuth as metal which can be treated electrolytically.

The material containing bismuth and copper is first oxidized, crushed and mixed with an alkali sulphide, or preferably with an alkali sulphate and carbon. Salt cake and coke breeze are suitable materials. The mixture is smelted in a reverberatory furnace provided with a cupelling breast that can be scraped down to follow the level of the charge. The fluxing ingredients are added in amount equal to about two and one-half times that indicated by the theoretical requirements for reduction and conversion of metals and salts. When the mass is fused and in a perfectly liquid state it consists of three layers: on top is the soda slag, in the middle the copper matte, and beneath is the bismuth. Gold and silver, if present, are mainly in the bismuth, but some will be in the matte. The slag and matte are drawn successively, leaving the bismuth metal. If it now contains less than 1 per cent copper, it may be cast into anode bars and refined. If the copper exceeds 1 per cent, the metal is again converted to oxide by blowing air through it and the oxide slag is skimmed over the cupel breast. This material is then again crushed and smelted with fluxes as before. If the bismuth contains considerable gold and silver, this reoxidation process may be performed for the purpose of recovering the precious metals, stopping the oxidation when but little bismuth remains and recovering the residue, which consists of a rich gold-silver-bismuth bullion. (1,098,854, June 2, 1914.)

Rare Metals

Extraction of Uranium, Vanadium and Radium from Ores.—Among the numerous proposals made for treating radium-bearing ores is that of Mr. J. H. Burfeind, of Nucla, Col. He claims that the treatment of carnotite (uranium-vanadium-radium ore) with sulphurous acid will yield a solution of uranium and vanadium, and a precipitate of radium-bearing material. His method is to agitate ground ore and water with sulphur dioxide, whereby uranium and vanadium are dissolved, and barium and radium precipitated as a fine slime. By allowing the gangue to settle for a brief interval after agitation, he claims that the barium-radium precipitate remains suspended in the uranium-vanadium solution and can be decanted with it. By passing the liquid through a filter press the radium precipitate is retained and the solution clarified. The latter is then heated to drive off sulphur dioxide, whereupon the sulphites of uranium and vanadium are precipitated, recovered and subjected to any further treatment desired. The radium precipitate also is subject to further refining. (1,095,377, May 5, 1914.)

Ductile Tungsten.—A method for preparing bodies of tungsten, molybdenum and similar refractory metals which can be drawn, bent and otherwise worked, is patented by Messrs. Paul Schwarzkopf and Siegfried Burgstaller, of Berlin, Germany. The operation is performed in two steps and consists of a combined reducing and sintering process. Tungsten oxide in powdered form is compressed into rods, producing relatively strong and coherent pieces of metal oxide. These rods are then subject to a temperature of 1100 to 1150° C. in a stream of hydrogen, with the result that the material is sintered and partly reduced. The next step is to heat the rods by a current of electricity in an atmosphere of hydrogen at a temperature of 2600 to 2700° C. The resulting rods are ductile and can be bent into a ring at red heat. (1,096,464, May 12, 1914.)

Ammonia

Ammonia from Calcium Cyanamid.—For the production of cyanamid first calcium carbide is made in an electric furnace; this is ground fine and charged into the cyanamid oven, where it is caused to react with nitrogen, forming calcium cyanamid, CaCN_2 . This cyanamid carries about 60 per cent. calcium cyanamid, about 25 per cent. lime, 12 per cent. graphite, and other impurities in minor quantities, derived principally from the presence of foreign materials in the lime and the reducing agent used in the carbide furnace. If such cyanamid is treated with steam, at a high temperature, the calcium cyanamid is broken up with the evolution of ammonia, $\text{CaCN}_2 + 3\text{H}_2\text{O} = 2\text{NH}_3 + \text{CaCO}_3$. The ammonia is evolved as a gas and there is left behind in the treating apparatus a sludge consisting of calcium carbonate, calcium hydrate, graphite and impurities. On account of its physical condition this sludge could not be economically treated again in the carbide furnace in the past. This is made possible, however, by an invention of Kenneth F. Cooper, of the American Cyanamid Co., of Niagara Falls, Ont., Canada. If in preparing the cyanamid for treatment with steam a small quantity of an alkaline or alkali salt (1 to 2 per cent equivalent of Na_2O in per cent of weight of cyanamid decomposed) is added, it affects in no way materially the evolution of ammonia, but when the resulting sludge is burnt in a rotary kiln or other calcination furnace, a porous clinker is produced of suitable size for carbide furnace charges. (1,100,539, June 16, 1914.)

Caustic and Chlorine

Sodium Chloride Electrolysis.—Mr. Herbert H. Dow, of the Dow Chemical Company of Midland, Mich., patents a diaphragm cell for the production of caustic soda and chlorine from brine solutions. The carbon anode is enclosed in a dome which covers one-half of the cell and extends downward some distance below the normal level of the liquor. The chlorine gas accumulates within the dome from which it is withdrawn. The cathode is provided in the form of a horizontal wire mesh in the open portion of the cell. A horizontal diaphragm forms automatically below the cathode by the precipitation of the insoluble hydrates of the impurities in the solution. (Patent 621,908, March 28, 1899.) The solution containing the cathode above the diaphragm is always pure sodium chloride, while impure brine is used as anolyte. (1,100,290, June 16, 1914.)

Synopsis of Chemical and Metallurgical Literature

Gold and Silver

Assaying for Gold and Platinum Metals.—The assay of precious metals existing in black sand, concentrates and "battery chips" from South African mills has attracted the attention of chemists in that country, resulting in the publication of a number of papers on the subject. In our issue for November, 1913, page 652, we reviewed two methods bearing on the subject. In the *Journal of the Chemical, Metallurgical and Mineralogical Society of South Africa*, February, 1914, Mr. Andrew F. Crosse makes a further contribution to the subject, believing that it is important to ascertain to what extent platinum and allied metals are being lost to the producers by being sold as gold bullion. His method for gold, platinum and osmiridium is as follows:

Having obtained lead buttons from the ordinary crucible assay, they are cupelled with the addition of

2 to 4 mg. silver. This large quantity of silver is advisable when much iridium is present. Having obtained a bead of silver from the cupellation, proceed as follows: Melt some pure cyanide of potassium in a porcelain crucible over a Bunsen burner, having the crucible about half full. Add metallic cadmium to the amount of three times the weight of the silver bead to be treated, and when the cadmium is melted and can be plainly seen through the molten cyanide, drop in the silver bead. It quickly alloys with the cadmium, and the crucible is given a rotary motion to insure thorough mixing of the alloy. Pour the melt into a warm mold, recover the alloy by dissolving the cyanide in hot water and digest the metal in dilute HNO_3 (1:3). Cadmium and silver dissolve, leaving the other metals as a black powder. Filter, wash and burn the residue in a platinum dish at low temperature. Melt the residue with 10 g. acid potassium sulphate to dissolve rhodium and palladium if present. Digest the melt in warm water, filter and wash. The residue contains gold, platinum and osmiridium. Dissolve in aqua regia, obtaining gold and platinum in solution and osmiridium as a black residue, which is filtered, washed, calcined and weighed. The filtrate is evaporated twice to dryness in a porcelain dish, with addition of a few drops HCl each time. Dissolve in water and precipitate gold with SO_2 . Filter and cupel the gold with lead. Precipitate platinum from the filtrate by acidifying with HCl and adding magnesium wire or ribbon. Filter, wash, calcine and weigh. The author states that he has made synthetical tests with gold and platinum and has obtained good results. In the discussion which followed the presentation of the paper, Prof. G. H. Stanley stated that he doubted if iridium is collected in the lead button in the ordinary crucible fusion. He believes that some of it goes into the slag, and that several re-assays of the slag may be necessary to collect all of it. He also stated that iridium is not easily filtered, even with the best papers. Mr. W. Cullen was of the opinion that the rarer precious metals existed in concentrates in sufficient quantity to make it worth while extracting them instead of allowing them to go out in gold bullion.

Zinc and Copper

Electrolysis of Fused Material Containing Zinc.—

A thesis by Mr. Chun Hao Wang presented for the degree of Ph.D. at Columbia University, contains an account of an experimental investigation carried out under the direction of Prof. E. F. Kern, on the freezing points of different zinc salt mixtures and the solubility of zinc sulphide and oxide in them. A longer review of this work is reserved for our next issue.

Leaching with Dorr Classifiers at Butte & Duluth Mine.—The use of modified Dorr classifiers in leaching oxidized copper ores is described by Mr. C. S. Herzog in *Bulletin* No. 116, Institute of Mineralogy and Metallurgy. Before adopting the present system the ore was treated by crushing to $\frac{1}{2}$ -in. and leaching for 48 hours in lead-lined vats with a 10 per cent sulphuric acid solution, following by a wash with water. The solution was precipitated by electrolysis or on iron. In order to improve extraction, experiments were made with Dorr classifiers in which wooden parts replaced metal that would come in contact with the acid solution. The first results were favorable, and the system finally adopted was as follows: The classifiers are 8 ft. wide and 30 ft. long, placed in series, the discharge of one falling into the next. The first four are for acid treatment and the last two for water washing. About 60 minutes' contact with acid is allowed. The ore is crushed to 10-mesh and is fed to the first classifier with solution from the first washing classifier. The overflowing slime passes to a vat be-

neath and is filtered through a bed of crushed ore. The coarse pulp progresses regularly through the line of classifiers. From the second, third and fourth machines, solution is drawn for precipitation by electrolysis. From the fifth the solution is used to mix with the original ore entering the first, and from the sixth the solution passes to precipitation on iron. Ten per cent sulphuric acid is used. The copper solution coming from the classifiers contains about 6 per cent acid and 4 to 5 per cent copper. Leaving the electrolytic plant, the solution contains about 8 per cent acid and $1\frac{1}{2}$ to 2 per cent copper. Earthenware pumps have proved superior to lead-lined in handling the acid solution. Hickory, maple and glass teeth have been tried on the classifiers, but maple and hickory have proved best.

Smelting

Handling Flue Dust.—The difficulty sometimes experienced in handling flue dust from blast furnaces prompts Mr. Erle Huntley to describe a simple method used for this purpose at the Hampden Cloncurry Copper Smelting Works, North Queensland. His paper appears in *Bulletin* No. 115, Institute of Mineralogy and Metallurgy. The furnace gases at this works are discharged into a collecting flue 9 ft. high and 7 ft. wide, and thence into a main settling flue 27 ft. high and 18 ft. wide. The increased area of this latter flue reduces the speed of the gas to about 240 ft. per minute. No baffle plates are used. The bottom of this flue is in the form of a trough, along which runs a $\frac{3}{4}$ -in. endless chain drawn by a sprocket wheel operated by a motor. The chain passes through the flue and returns along its top, being supported by pulleys. The chain travels at the rate of 40 ft. per minute, and is operated 6 hours per day. This suffices for the removal of about 12 tons flue dust, which is delivered into a collecting hopper in the bottom of the flue. In discussing this paper (*Bulletin* No. 116) Mr. T. C. Cloud suggested that the attachment of discs to the chain would be more effective. No mention being made as to the method of closing the flue where the chain passed through its walls, Mr. Cloud suggested that if discs were used the chain might pass through tubes just about the diameter of the discs and long enough always to insure the presence of two discs in the tube, thus keeping the openings closed to the admission of outside air. Mr. S. J. Speak questioned whether dust losses by way of the stack could be avoided when the gas had a velocity of 240 ft. per minute, or 4 ft. per second, as it had been his experience that appreciable loss occurred at this velocity.

Crushing and Grinding

Kick's Law of Crushing.—Mr. S. J. Speak makes a further contribution on the subject of crushing and grinding, giving in *Bulletin* No. 116, Institute of Mineralogy and Metallurgy, his views on the application of Kick's law to the measurement of energy consumed in crushing. Kick's law is stated by Stadler as follows: "The energy required for producing analogous changes of configuration of geometrically similar bodies of equal technological state varies as the volumes or weights of these bodies." Mr. Speak points out an important limitation to the correctness of this law, in that it assumes that the tenacity of a material is a constant quantity. This assumption is true for sizes appreciable by the naked eye, but does not hold good for fine sizes. He cites the enormous increase in tenacity in fine threads of spun glass and metallic wire, and shows that Kick's law becomes more and more inaccurate as sizes of rock or ore become finer. Another point of limitation is that ore is not a body of "equal technological state." It may contain vugs

filled with soft, powdery material, or cracks filled with clay. The first fractures will take place along cleavages and weak places. Consequently the tenacity of a piece of such ore 4 in. in diameter will be much less than of a piece 1/10 in. in diameter. Further, much of the ore may be converted into slime without the expenditure of much energy. In general, the author comes to the following conclusions regarding the applicability of Kick's law, believing that they are borne out by actual experience.

1. It will tend to overestimate the energy consumed in coarse crushing.

2. It will tend to underestimate the energy consumed in grinding non-slimy sand to slime.

3. It will tend to overestimate the work done in making slime from such ores as contain slime as an original constituent.

Graphic Record of Screen Analysis.—In order to convey quickly to the mind the results of a screen analysis of crushed ore, Mr. S. J. Speak has shown in *Bulletin No. 116*, Institute of Mineralogy and Metallurgy, a method for graphically recording the results. Fig. 1 shows the graphic record of the figures given below:

| Screen Mesh | Aperture Inches | Percentage in Tube Mill Feed | Percentage in Tube Mill Discharge |
|-------------|-----------------|------------------------------|-----------------------------------|
| 12 | 0.03937 | 27.6 | ... |
| 20 | 0.02480 | 15.7 | ... |
| 30 | 0.01562 | 13.7 | 7.4 |
| 50 | 0.00984 | 19.9 | 22.5 |
| 80 | 0.00620 | 15.5 | 29.0 |
| 120 | 0.00391 | 2.0 | 6.0 |
| 200 | 0.00246 | 1.6 | 7.7 |
| 250 | ... | 4.0 | 27.4 |

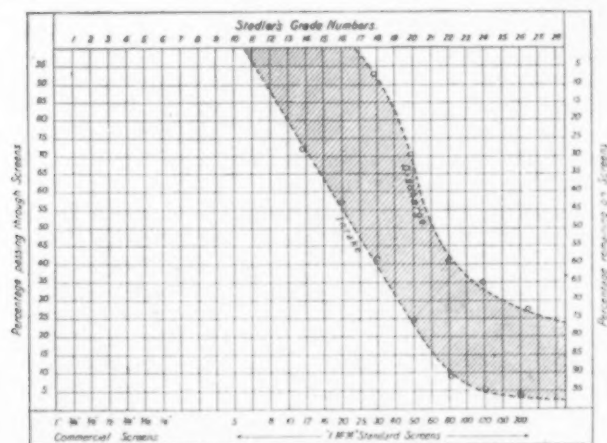


FIG. 1—GRAPHIC RECORD OF SCREEN ANALYSIS

Referring to Fig. 1, the left-hand lower portion of the diagram represents the energy already expended on the ore, and the right-hand upper corner shows the work remaining to be done to reduce the ore to the finest grade. The shaded portion represents the useful work done by the tube mill, which can be measured more readily and satisfactorily than by the mathematical method used by Stadler.

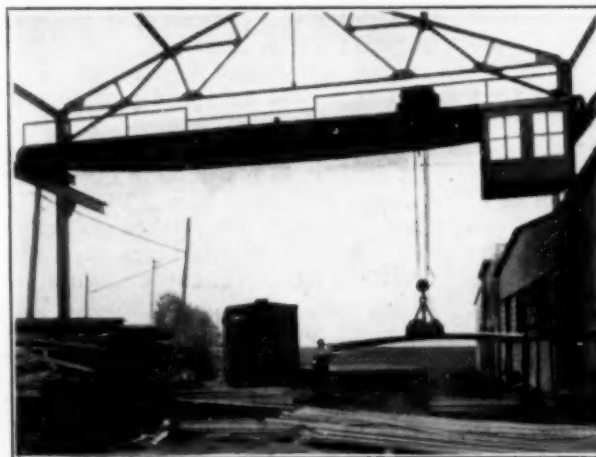
An Economic Way to Handle Shipment of Long Iron Rods

The recent installation of a Shaw electric crane at the plant of the Bayonne Bolt & Nut Company of Bayonne, N. J., illustrates in a pretty manner how a difficult problem of handling material was solved by the application of a few small strands of wire.

The Bayonne Bolt & Nut Company receive quantities of bar stock-iron rods about twenty feet in length, and ranging in diameter from one-quarter inch upward. This raw material comes in gondola cars on the company's private switches.

The unloading and stacking of the rods by hand was, however, a slow process. The rods had to be lifted, one at a time, from the cars and carried to various parts of the yard. From the flexible and yielding nature of the material the "stocking" of a shipment was necessarily slow and, of course, expensive.

In seeking a better way to do the work an electric crane and magnet naturally suggested themselves, but the nature of the material to be handled again interposed an obstacle. With the rods lying loosely in the car a hoisting magnet could not pick up a clean load. Some rods would hang and swing. To obviate this, the expedient of having the consignors wire the rods together in bundles was adopted. With the rods in bundles it became possible to employ an electric crane and a magnet economically and the apparatus was installed by the Shaw Electric Crane Company. With



ELECTRIC CRANE FOR HANDLING IRON RODS

the bar stock in bundles the magnet makes a clean lift not merely of one bundle, but of bundles up to its lifting capacity.

They are raised out of the car and piled practically at one operation. With the crane and magnet the company can now accomplish in a few minutes work which under the old method took a gang of freight handlers hours to do.

There is besides the saving in labor a gain in the speed of handling raw material. Furthermore, the use of the crane permits the piling of rods to a greater height than would have been economically possible by hand work.

Filter Press Experience in a Cuban Sugar Plant

In our Vol. IX, page 381 (July, 1911), we noticed some interesting development work on filter presses carried out by Mr. John J. Berrigan, and in our Vol. XI, page 286 (May, 1913), we stated that the Berrigan filter press has been taken over by the Hy. R. Worthington Pump Company, of Harrison, N. J. The following report of the commercial operation of a Worthington filter press at Central Armonia, Bolondron, Cuba, should be of particular interest.

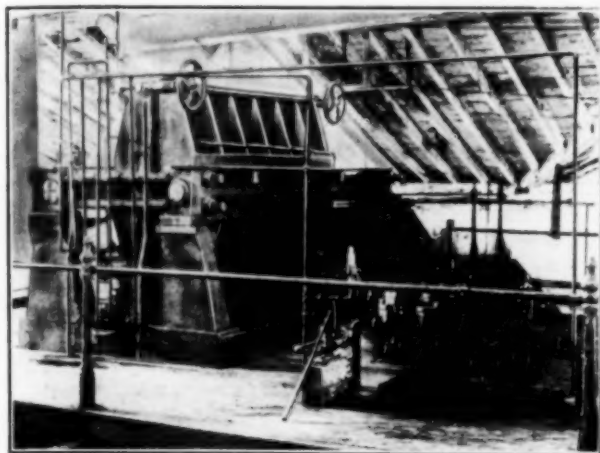
In actual continuous operation during the past crop for over a month at the Central Armonia for filtering cachaza, the Worthington filter press is stated to have shown the following advantages over the old-style frame presses in use in Cuban mills.

1. *Greater Efficiency.* A great saving of time is effected in the opening and closing of the press; in the dropping of the press cake and the placing of the filter

bags, as well as a great saving of labor expended. This permits of the press being idle but a very small percentage of the time.

The average capacity of the press may conservatively said to be at least 400 gal. of cachaza per hour. One press will do practically the work of four thirty-frame presses, rated at 1/3 m filtering surface per frame.

The filter bags can be used several times over without washing. On one test at the Central Armonia, the same



WORTHINGTON FILTER PRESS IN CUBAN SUGAR PLANT

set of bags was used continuously for fifty-six hours without washing.

The simplicity of operation allows the employment of ordinary unskilled labor, there being no danger of breakage or of getting the press out of order.

2. *Economy in Operation.* Three men are sufficient to operate a battery of three presses which is sufficient to filter the cachaza resulting from a daily grind of 80,000 arrobas (1000 tons) of cane, including the washing of the bags, thus reducing from one-half to two-thirds the labor cost of operating the old-style frame presses.

3. *Saving in Material.* As but three bags are used in the filtering process a great saving is effected in filter cloth material used. Five sets of bags should be ample to make a crop, at a total cost of about \$100 per press for material. Therefore, on the basis of a mill grinding 80,000 arrobas of cane every twenty-four hours and with three Worthington presses in use for filtering the cachaza, the total cost for filter cloth material should not be over \$300 for the crop, as against a cost of from \$1,000 up for filter cloths needed in operating the old-style frame presses.

There is very little tearing of the bags, which eliminates a considerable expense for repair of filter cloths.

4. *Better Results Obtained in Filtered Juice and Press Cake.* The juice is filtered perfectly, a brilliant liquor resulting, and entirely free from all small particles of fiber and other materials detrimental to elaboration.

The press cake is always well formed and can be removed from the bag very easily. The press cake shows from 10 per cent to 20 per cent less sucrose content than that shown in the cake resulting from the old-style frame presses under equal conditions.

5. *Economy for Repairs.* As there are no parts about the press than can be easily broken, the expense of replacing broken plates and frames is eliminated. The cost of upkeep on the press is practically negligible.

In Table I data are given as to the actual results obtained in operation of the Worthington filter press at the Central Armonia, during the crop just ended.

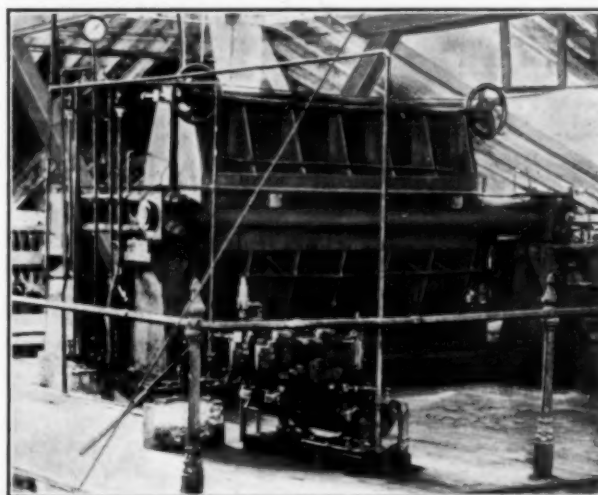
TABLE I—TESTS RUN AT CENTRAL ARMONIA WITH WORTHINGTON FILTER PRESS

| | 1 | 2 | 3 | 4 | 5 Av. |
|--|------|------|------|------|-------|
| Minutes required to fill bags with cachaza | 3.5 | 2.5 | 3.0 | 2.0 | 2.75 |
| Minutes required to close press and make seal | 2.5 | 3.0 | 3.5 | 4.5 | 3.38 |
| Minutes required lowering press without pressure | 6.5 | 7.0 | 14.0 | 12.0 | 8.88 |
| Minutes required to close press under hydraulic pressure | 21.0 | 29.0 | 17.0 | 10.0 | 19.25 |
| Minutes required to raise press and drop bags with cake | 9.0 | 3.5 | 3.0 | 3.5 | 4.75 |
| Minutes required to put in empty bags | 4.0 | 4.0 | 6.0 | 6.5 | 5.12 |
| Total minutes required for complete operation of press | 46.5 | 49.0 | 46.5 | 38.5 | 45.13 |
| Gallons of cachaza per charge | 291 | 304 | 290 | 278 | 291 |
| Gallons cachaza filtered per hour (rate) | 375 | 372 | 374 | 433 | 388 |
| Degrees Brix of filtered juice | 9.75 | 14.4 | 10.7 | 13.8 | 12.16 |
| Percent Sucrose of filtered juice | 8.10 | 12.6 | 9.1 | 11.9 | 10.42 |
| Percent purity of filtered juice | 83.2 | 87.2 | 85.1 | 86.5 | 85.50 |
| Pounds of press cake | 184 | 192 | 168 | 172 | 179 |
| Percent Sucrose in press cake | 5.4 | 7.0 | 6.4 | 7.2 | 6.85 |
| Percent moisture in press cake | 58.2 | 58.4 | 57.8 | 59.3 | 58.42 |
| Thickness of cake in inches | | | | | 5/8 |

The above tests were conducted under circumstances somewhat unfavorable to obtaining the most advantageous results as to the maximum efficiency of the press. With an installation of the press in a manner to allow of time saving, in the filling of the bags with cachaza, dropping the bags with cake and putting in of empty bags, the time required for complete operation of the press could be reduced from the above figures.

The press in action had 300 ft. of filtering surface.

The comparison made in Table II of the Worthington filter press with one of the latest type cylinder presses in use in some sugar factories will prove of considerable interest.



WORTHINGTON FILTER PRESS IN CUBAN SUGAR PLANT

TABLE II

| | Worthington. Average | Late Type of Cylinder Press. Average |
|--|-------------------------|--|
| Total minutes required for complete operation of press | 45.13 | 160 |
| Gallons of cachaza per charge | 291 | 750 |
| Gallons of cachaza filtered per hour (rate) | 388 | 280 |
| Degrees brix of filtered juice | 12.16 | 14.5 |
| Percent sucrose of filtered juice | 10.42 | 11.1 |
| Percent purity of filtered juice | 85.50 | 76.6 |
| Percent sucrose in press cake | 6.85 | 8 |
| Percent moisture in press cake | 58.42 | 79.2 |
| Thickness of cake in inches | 5/8 | 5/8 |

Electric Annealing Furnace for Brass and German Silver Ware

An interheating electric furnace for annealing brass and German silver flat ware blanks has just been installed in the plant of one of the best known makers of plated ware in this country, located at Niagara Falls, New York.

The furnace framework is made of steel shapes and plates, and is 15 ft. long, 8 ft. wide, 7 ft. 6 in. high. The doors are located at both ends of the furnace.

A mechanical pusher operated by compressed-air cylinders running over cast-iron idler sheaves operates the pusher mechanism located at the charging end of the furnace. The material under treatment is packed

and is taken out through the counter-balanced swing door shown in Fig. 2.

The material dumped into the quenching tanks falls into a perforated copper basket, which is lifted at intervals out of the quenching tank.

At the same time that the pan-dumping mechanism starts to tilt, the pusher carriage is pulled out of the charging end of the furnace by the counterbalanced door shown in Fig. 1, and immediately after the carriage clears the opening the two doors drop too, simultaneously. It will thus be seen with this furnace that the material is not exposed to the atmosphere at any time after entrance to the furnace until it is taken from the quenching tank cold. This entirely eliminates any possibility of oxidation at any stage during the heating or cooling, as the furnace itself has a reducing atmosphere at all times.

The electrical equipment consists of a special 200-kilovoltampere transformer, built by the Pittsburgh Transformer Company, and arranged with 12 voltage taps so connected to the special controller shown in Fig. 1. The switching mechanism is so connected with the transformer leads that a very fine regulation of the voltage, and

hence the wattage, may be readily obtained. This switch is mounted on a switchboard frame and is located directly in front of the transformer, as shown in Fig. 1. The instruments on the switchboard panel consist of a Weston watt-meter and Foxboro pyrometer. The latter is connected up with a 48-inch couple placed

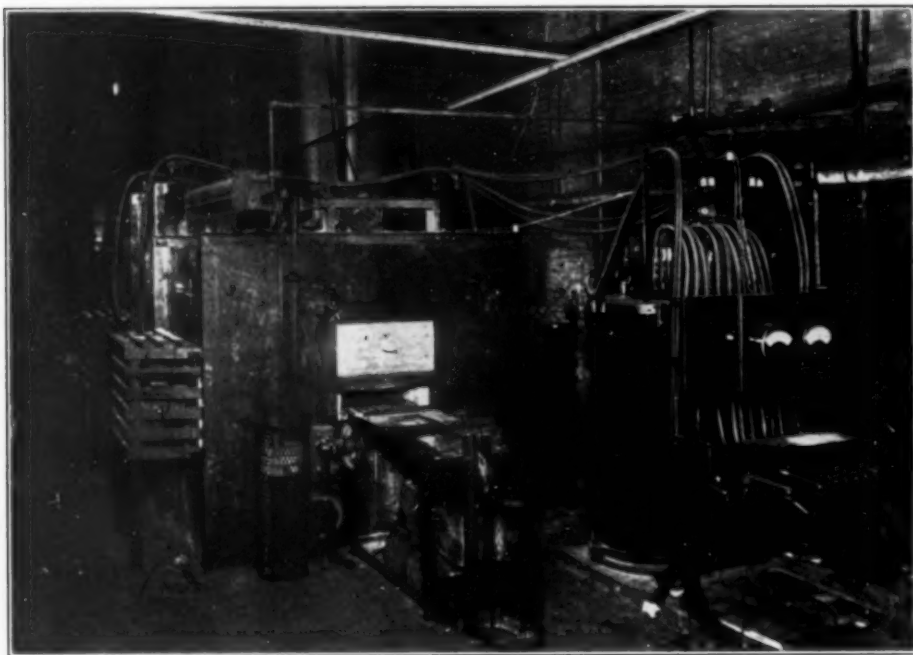


FIG. 1—FRONT END OF FURNACE AND ELECTRIC FURNACE

in steel pans 20 inches square which are forced through one after another, seven pans being in the furnace at one time. The pans passing through the furnace are supported by a hearth made of cast-iron grids 24 inches square, and are of special design, which prevents undue warping at furnace temperatures.

The pan coming out of the discharge end of the furnace is automatically dumped into a water-sealed discharge hood. The metal under treatment falls into a tank of either clear water or pickling solution, depending upon the cleanliness of the material before it is charged into the furnace. The pan itself is caught by two rails and held suspended above the trough and may be taken out from under the water sealed hood through the counter-balance swing door shown in Fig. 2.

The operation of the furnace is as follows:

A pan of flat ware is placed on the runway in front of the pusher—as shown in Fig. 1. The small hand lever shown near the top of the furnace frame in Fig. 1 is pushed upwards, which operates the air valve on the cylinder shown on the top of the furnace in the same figure. The first movement of the cylinder raises both the front and the rear doors to a sufficient height to admit the pans, which are 3 inches high.

At this point a stop on the cable holds the doors at this height and the pusher with the pan of fresh material starts into the furnace, pushing ahead of it the seven pans already in the furnace. At the moment the fresh pan is completely inside the furnace, the pan at the discharge end has been pushed clear of the furnace opening and door onto a dumping carriage. The weight of the pan striking the base of this carriage automatically tips the pan and it turns completely over, dumping the contents in a hopper, the lower end of which is submerged in the quenching tank. The pan, now upside down, is caught by two rails and held above the water

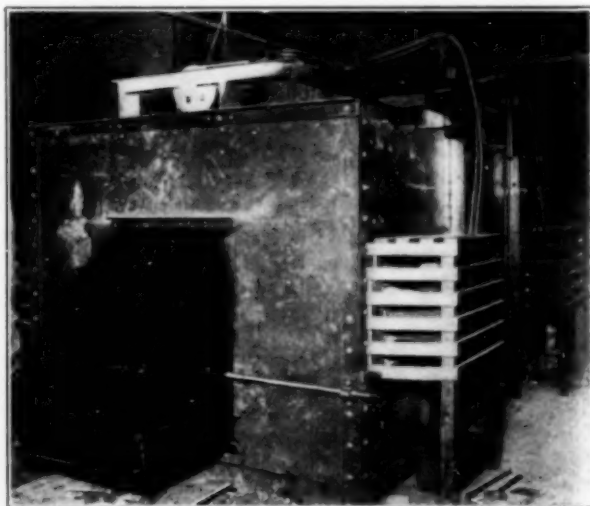


FIG. 2—DISCHARGE END OF FURNACE

directly over the pan about to be pushed out of the furnace, thus making it possible to know exactly at what temperature the material is drawn.

The operation of this furnace has demonstrated clearly the superiority of continuous electric furnaces for the class of work handled, as the desired temperature may

be reached with the utmost precision and without danger of overheating, and the ruling temperature at the end of the furnace is no higher than the temperature desired in the metal; and, further, the furnace atmosphere being always reducing and the material discharged from the furnace quenched from a sealed hood, eliminates the two most undesirable features usually found in fuel-fired furnaces; namely, lack of uniformity in temperature and oxidizing atmosphere.

This furnace was designed and installed by The Electric Furnace Company of America, Alliance, Ohio, who have recently received a duplicate order for a furnace of the same size and capacity for installation in the same plant.

Personal

At the fiftieth anniversary of the Columbia School of Mines the honorary degree of Master of Science was conferred upon **John A. Church**, '67; **Wheaton B. Kunhardt**, '80; **Carl A. Meissner**, '80; **Arthur H. Elliott**, '81; **Francis B. Crocker**, '82; **J. Parke Channing**, '83; **Robert V. A. Norris**, '85; **Arthur S. Dwight**, '85; **Rudolph P. Miller**, '88; **Frederick W. Denton**, '89; **Karl E. Eilers**, '89; and **Gano Dunn**, '91; while the degree of Master of Arts was conferred upon **Henry F. Hornbostel**, '91 and **Goodhue Livingston**, '92.

Oberbergat Professor **Dr. F. Kolbeck**, rector of the Bergakademie of Freiberg, Germany, was the official representative of Freiberg at the Columbia School of Mines celebration. He used the next few weeks for various trips to the Canadian cobalt district, Washington, D. C., the Franklin Furnace zinc mine, the Chrome (N. J.) copper refinery, etc. Before sailing for Europe he was the guest of honor at a dinner given by the Old Freibergers in America.

Dr. Joseph W. Richards has sailed for a professional and pleasure trip to Norway.

Professor **Hans Goldschmidt** of Essen-Ruhr, Germany, president of the German Bunsen Society and widely known as the inventor of the aluminothermic process and of electrolytic detinning, and Professor **Paul Askenasy** of the Institute of Technology of Karlsruhe, editor of the *Zeitschrift für Electrochemie*, were the guests of honor at an informal dinner given on June 8th at the Chemists' Club by the New York Section of the American Electrochemical Society. **Dr. C. G. Fink**, chairman of the section, presided and speeches were made by **Dr. Baekeland**, **Dr. Goldschmidt**, **Dr. Askenasy**, **Dr. J. W. Richards**, **Dr. Alexander Smith**, and **Dr. C. F. Chandler**.

Dr. A. S. McAllister, editor of *Electrical World*, has been elected president of the Illuminating Engineering Society.

Mr. Charles F. Rand, President of The Spanish-American Iron Company, Past President of American Institute of Mining Engineers, has been made a member of the Order of Isabella Catolica and decorated by the King of Spain with the Grand Cross of a Knight Commander.

Mr. F. E. Pierce has terminated his connection with The New Jersey Zinc Co. in whose employ he has served for over fifteen years in various capacities, for the latter part as chief engineer, and has opened an office to engage in consulting work in civil and metallurgical engineering at 35 Nassau street, New York City.

Mr. H. W. Hardinge, president of the Hardinge Conical Mill Company, has left New York for a combined business and professional trip which will include the Cobalt, Porcupine and British Columbia districts of Canada and Alaska, as well as the Western mining states. He will return in the second week of August.

Dr. Richard Amberg severed last January his connection with the Crucible Steel Company of America, where he was in charge of their new electric Heroult furnace, in order to accept the position of assistant manager of the Eisen-Industrie Menden-Schwerte, Germany.

Digest of Electrochemical in U. S. Patents

PRIOR TO 1903.

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Electroplating (Continued)

349,535, September 21, 1886, **Andreas Söhner**, of Karlsruhe, Baden, Germany.

Relates to a process of renovating gold and silver lace trimmings, real or imitation, and consists, first, in dissecting the trimmings into their several parts, such as metal, and metal-coated fabrics, cleaning the parts by subjecting to the action of steam to soften and remove greasy and other impurities, then subjecting the articles to solutions of soda and Panama bark, to remove further traces of grease, etc., then to a solution containing hydrochloric acid to neutralize and remove the alkali, then to a brushing with tartaric powder, then to the action of a silvering or gilding bath, and then to a final polishing.

360,517, April 5, 1887, **James E. Emley**, of Weatherford, Tex., assignor to **W. J. Carson** and **T. D. Lewis**, both of same place.

Relates to apparatus for recutting files, and consists in connecting a file to one terminal of a source of current, a carbon plate to the other, and immersing the file and carbon in an electrolyte, such as sulfuric or other acid, or caustic potash, or salt water. A plurality of files may be so treated at once by connecting each file between a pair of carbon plates.

The patent does not state whether the file is to be connected as anode or cathode.

362,257, May 3, 1887, **William L. Dudley**, of Covington, Ky., assignor to the American Iridium Company, of Cincinnati, Ohio.

Relates to electrodepositing iridium. An electrolyte of either the double chloride of iridium and sodium, or the double chloride of iridium and ammonium is used, containing about two ounces of metal and about one-half ounce of free sulfuric acid to the gallon of solution. From both of these solutions a thick, bright and reguline deposit is obtained, using as anode either a plate of iridium or of phosphide of iridium, the latter made by the process described in patent 240,216, dated May 10, 1881. During the plating operation it is necessary to avoid a current of too great intensity, which causes a dark powdery deposit; alkaline solutions should also be avoided.

367,731, August 2, 1887, **William Arthur Thoms**, of London, County of Middlesex, England, assignor to the Bright Platinum Plating Company (Ltd.), of same place.

Relates to an electrolyte for electrodepositing platinum, from which a bright white deposit of a fine, close reguline nature is said to be obtained. The proportions of the electrolyte may be varied, but the following are said to give good results: One ounce of chloride of platinum, twenty ounces of phosphate of soda, four ounces of phosphate of ammonia, and one ounce of chloride of sodium, all dissolved in water and diluted to a gallon of solution. A strong current of electricity should be employed—states a current of twelve amperes at ten volts; fresh platinum solution and chloride of sodium should be added to keep up the original strength.

429,386, June 3, 1890, Myron W. Parrish, of Detroit, Mich., assignor to the Graphite Electric Company, of same place, and John Hutchinson, of Jackson, Mich.

Relates to separating impurities from native graphite, and consists in connecting pieces of graphite, before crushing, as an electrode and short-circuiting in an electrolyte of sodium chloride with an electrode of zinc. The impurity said to be generally present is iron, although other metals may be present.

434,884, August 19, 1890, Charles C. Peters, of Springfield, Ohio, assignor of two-thirds to John V. B. Hoyle, and Charles W. Wadsworth, both of same place.

Relates to recutting files by electrolysis. The files are connected as anodes, in parallel, using carbon, etc., as cathode. The electrolyte preferred is not stated, but should have the properties of normally feeble and slow action upon the iron or steel of the file, but which will become rapid and caustic under the influence of an electric current.

437,648, September 30, 1890, Myer Hecht, of New York, N. Y.

Relates to ornamenting wood, ivory, or other non-metallic surfaces, such as umbrella handles, work-boxes, etc., by suitably engraving or carving figures thereon, as by channeling, and undercutting the side walls at such points as are essential to hold the metal. The engraved or channeled portions are now treated with plumbago, iron fillings, etc., in order that metal may be electrodeposited therein. When completed, the deposited metal is ground smooth and then electroplated with the desired finishing metal.

448,144, March 10, 1891, Augustin Personne de Sennevoy, of Paris, France.

Relates to recutting files, rasps, etc., and also engravings on steel, copper, zinc or other metals, and to the re-etching of steel and copper plates, and to the renovation of damaskened articles. It consists in making the file, etc., the anode of a battery and short-circuiting with a carbon cathode in an electrolyte of one hundred volumes of water, six volumes of nitric acid and three volumes of sulfuric acid.

Book Reviews

The Steel Foundry. By John Howe Hall. Octavo (15 x 23 cm.), 271 pages, 37 illustrations; price \$3.00. New York: McGraw-Hill Book Company, Inc.

The book is written by an engineer thoroughly competent to write on the chemistry, metallurgy and engineering involved. It is eminently practical, in that it keeps the dollar mark thoroughly in evidence in the descriptions and discussions. A long chapter on general considerations is very interesting reading, as it summarizes and compares in a clear and convincing manner the advantages and disadvantages of each method of making steel for foundry purposes, including detailed analyses of costs. A very strong case is made out for electric furnace steel, which it is predicted will entirely replace crucible steel; the thermal efficiencies of electric furnaces, however, negative the statement that they are less economical of electric power than other furnaces are of fuel energy—the reverse is the case. Among the raw materials we note the omission of the soft iron sponge which is being made so cheaply and extensively in Sweden; and in the open-hearth furnace chapter no allusion is made to the combined producer and furnace so successfully used in Europe.

However, where there is so much that is valuable and good, and also original, it is perhaps captious to note these few defects. Perhaps still more unimportant are the frequent omission of the zero before a decimal number (e. g., .95 instead of 0.95), the use of

such expressions as "15 per cent of manganese" for "15 per cent manganese," and some uncertainties of expression which come direct from the foundry. The work as a whole is worthy of hearty endorsement; it will be of great service to all engaged in making steel castings.

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Engineers' Hand-Book of tables, charts and data on the application of centrifugal fans and fan system apparatus, including engines and motors, air washers, hot blast heaters and systems of air distribution. Published by The Buffalo Forge Company, Buffalo, N. Y. Edited by Willis H. Carrier, First Edition (1914), 581 pages. Price \$3.00. Buffalo, N. Y. The Buffalo Forge Co.

This is in more than one respect a remarkable book. It is the first complete and reliable treatise on fans and their standard applications to various industrial requirements. It is intended to be used as a guide in the selection and application of fans, heaters and kindred apparatus, and an effort has been made so to standardize the rules and data given that they may be used with any standard make of equipment. A technical reference book of this kind is rarely prepared by a manufacturing company; that the Buffalo Forge Company has succeeded in bringing out a volume of so much technical value and absolutely free from talkative self-advertising, is a credit to its engineering staff and a fine indirect advertisement for the company itself.

The amount of information contained in this little handy volume which can be conveniently carried in the pocket is enormous. This was made possible by utmost conciseness in the text and by giving most of the technical information in the universal short-hand system of engineers, that is, in form of diagrams, tables and formulas.

In the first chapter (35 pages) data on the properties of air are collected (weight of air; specific heat of air; relation of velocity to pressure; effects of temperature, humidity and barometric pressure on the properties of air; relation of dry-bulb, wet-bulb and dew-point temperatures; sensible, latent and total heat; psychometric charts and tables).

The second chapter (65 pages) deals with the applications of fans (heating; ventilating; air washing, cooling, humidifying, drying, mechanical draft; exhaust systems; miscellaneous applications).

The third chapter on "air ducts" gives detailed information on the design of various duct or conduit systems used for the conveying of air. The data on pressure losses and friction in piping and elbows are based on actual tests, many of which were specially made for this book.

The subject of proper proportions of piping in different systems, as well as the proper velocity of air, is also completely covered.

In part IV (356 pages) on "apparatus" the products of the Buffalo Forge Co. and the Carrier Air Conditioning Co. are, of course, primarily covered. Since the essential elements in most installations, using fans, are the fan, heater ducts or piping system, and some form of motive power for driving the fan, this section gives complete data relative to the performance and dimensions of fans, heaters and engines, together with detailed directions for carrying out fan tests.

Data on the performance and dimension of cast iron heaters are also given.

An appendix gives specifications and various reference tables for engineers.

The editor and publisher must be sincerely congratulated.